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SATURN S IVB 202 STAGE
FLIGHT EVALUATION REPORT

DOUGLAS REPORT SM-46987
30 JUNE 1966

MISSILE & SPACE SYSTEMS DIVISION
DOUGLAS AIRCRAFT COMPANY, INC.
SANTA MONICA/CALIFORNIA

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FLIGHT EVALUATION REPORT

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OCTOBER 1966

PREPARED BY:
SATURN S-IVB TEST PLANNING AND
EVALUATION COMMITTEE
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SATURN DEVELOPMENT ENGINEERING

PREPARED FOR:
MARSHALL SPACE FLIGHT CENTER
UNDER NASA CONTRACT NAS7-101

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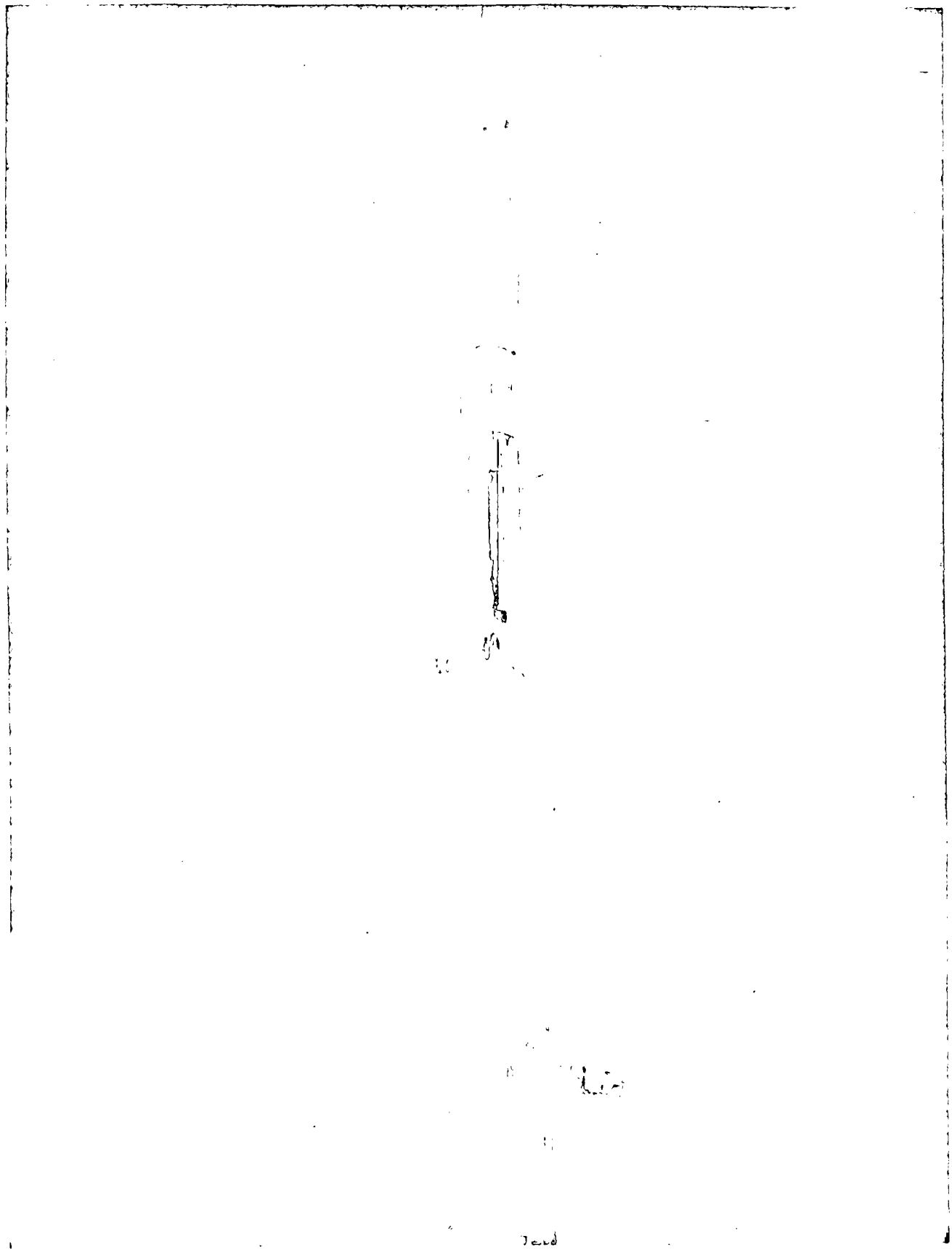

SATURN AS-202 VEHICLE LIFTOFF

24 October 1966

ABSTRACT

This report presents the evaluation results of the pre-launch countdown, powered flight, and sub-orbital phase of the S-IVB-202 stage which was launched on 25 August 1966 as the second stage of the Saturn AS-202 vehicle.

All flight objectives were satisfied and the stage and ground support equipment functioned as anticipated.

The report is a contractual document as outlined in DAC Report No. SM-41410: Data Submittal Document, Saturn S-IVB System, dated March 1966. It was prepared by the Saturn S-IVB Test Planning and Evaluation Committee and coordinated by the Saturn S-IVB Project Office of the Douglas Aircraft Company, Inc., Missile and Space Systems Division.

DESCRIPTORS

data evaluation	S-IVB-202
flight test	Saturn AS-202 Vehicle
Saturn IB	countdown

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II.

PREFACE

The purpose of this report is to document the evaluation of the S-IVB-202 flight stage which was launched from Kennedy Space Center on 25 August 1966.

This report, prepared in compliance with the National Aeronautics and Space Administration Contract NAS7-101, is published in accordance with DAC Report No. SM-41410: Data Submittal Document, Saturn S-IVB System, dated March 1965, which delineates the data required from the Douglas Aircraft Company, Inc.

This document was prepared by the Saturn S-IVB Test Planning and Evaluation Committee and coordinated by the Saturn S-IVB Project Office of the Douglas Aircraft Company, Inc., Missile and Space Systems Division.

PAGE MISSING FROM AVAILABLE VERSION

TABLE OF CONTENTS

Section		Page
1.	INTRODUCTION	1
2.	SUMMARY	3
	2.1 Countdown Operations	4
	2.2 Trajectory	4
	2.3 Mass Characteristics	5
	2.4 Engine System	5
	2.5 Solid Rockets	5
	2.6 Oxidizer System	6
	2.7 Fuel System	6
	2.8 Auxiliary Propulsion System	6
	2.9 Pneumatic Control and Purge System	6
	2.10 Propellant Utilization	6
	2.11 S-IB/S-IVB Separation	7
	2.12 Data Acquisition System	7
	2.13 Electrical System	7
	2.14 Range Safety System	8
	2.15 Flight Control	8
	2.16 Hydraulic System	8
	2.17 Stage Structure and Environment	9
	2.18 Forward Skirt Thermoconditioning System	9
	2.19 Acoustic and Vibration Environment	9
	2.20 Aero/Thermodynamic Environment	9
	2.21 Sub-Orbital Coast Phase	10
3.	CONFIGURATION	11
	3.1 Stage Configuration	11
	3.2 Stage Modifications	14
	3.3 Ground Support Equipment	16

TABLE OF CONTENTS (Continued)

Section		Page
4.	SEQUENCE OF EVENTS	27
	4.1 Predicted and Monitored Times	27
	4.2 Time Bases	28
	4.3 Ground Sequence of Events	28
5.	COUNTDOWN OPERATIONS	55
	5.1 Propulsion System Checkouts	55
	5.2 Launch Vehicle Tests	55
	5.3 Countdown Demonstration Test	56
	5.4 Launch Countdown	57
	5.5 Environmental Control System	61
	5.6 Terminal Countdown	62
	5.7 Holds	62
	5.8 Launch Environment	63
6.	TRAJECTORY	69
	6.1 Comparison Between Actual and Preflight Predicted Trajectories	69
	6.2 Postflight Predicted Trajectory Analysis	70
7.	MASS CHARACTERISTICS	89
	7.1 Ice/Frost Formation	89
	7.2 Adapter Panels	89
8.	ENGINE SYSTEM	95
	8.1 Engine Chilldown and Conditioning	95
	8.2 Engine Performance	97
	8.3 Sequence of Events	102
	8.4 Component Operation	102
	8.5 Flight Simulation Analysis	105

TABLE OF CONTENTS (Continued)

Section		Page
9.	SOLID ROCKET PERFORMANCE	137
	9.1 Ullage Rockets	137
	9.2 Retrorockets	137
10.	OXIDIZER SYSTEM	147
	10.1 Pressurization Control and Internal Environment	147
	10.2 Cold Helium Supply	149
	10.3 Heat Exchanger	150
	10.4 LOX Chilldown	151
	10.5 Engine LOX Supply	153
11.	FUEL SYSTEM	165
	11.1 Pressurization Control and Internal Environment	165
	11.2 LH2 Chilldown	167
	11.3 Engine LH2 Supply	169
	11.4 LH2 Boiloff	170
	11.5 Recirculation Shutoff Valve Anomaly	171
12.	AUXILIARY PROPULSION SYSTEM	181
	12.1 APS Module No. 1	181
	12.2 APS Module No. 2	182
	12.3 Engine Performance	184
13.	PNEUMATIC CONTROL AND PURGE SYSTEM	193
	13.1 Ambient Helium Supply	193
	13.2 Pneumatic Control	194
	13.3 Ambient Helium Purges	194
14.	PROPELLANT UTILIZATION	201
	14.1 Propellant Mass History	201
	14.2 PU System Analysis	203
	14.3 PU Efficiency	209

TABLE OF CONTENTS (Continued)

Section		Page
15.	S-IB/S-IVB SEPARATION	227
	15.1 Separation Distance	227
	15.2 Stage Accelerations and Angular Velocities	227
	15.3 Relative Lateral Motion	228
16.	DATA ACQUISITION SYSTEM PERFORMANCE	241
	16.1 Instrumentation System Performance	242
	16.2 Telemetry System	242
17.	ELECTRICAL SYSTEM PERFORMANCE	255
	17.1 Electrical Control System	255
	17.2 Electrical Power System	256
18.	RANGE SAFETY SYSTEM PERFORMANCE	261
	18.1 Controllers	261
	18.2 Firing Units Monitors	261
	18.3 Receivers Signal Strength	261
19.	FLIGHT CONTROL	263
	19.1 Main Engine Control System	264
	19.2 Roll Control During S-IVB Powered Flight	267
	19.3 Sloshing	268
	19.4 Body Bending	270
20.	HYDRAULIC SYSTEM	287
	20.1 Hydraulic Systems Operation	287
	20.2 Servo System Operation	287
21.	STAGE STRUCTURE AND ENVIRONMENT	291
	21.1 Flight Load Conditions and Structural Integrity	291
	21.2 Explosive Ordnance Equipment	294

TABLE OF CONTENTS (Continued)

Section		Page
22.	FORWARD SKIRT THERMOCONDITIONING SYSTEM	301
	22.1 Temperature	301
	22.2 Pressure	301
	22.3 Flowrate	301
23.	ACOUSTIC AND VIBRATION ENVIRONMENT	305
	23.1 Data Acquisition and Reduction	305
	23.2 Vibration Environment	306
	23.3 Acoustic Environment	309
24.	AERO/THERMODYNAMIC ENVIRONMENT	349
	24.1 Thermodynamic Environment	349
	24.2 Aerodynamics	357
	24.3 Component Heating	359
25.	SUB-ORBITAL COAST PHASE ANALYSIS	385
	25.1 Common Bulkhead Experiment	385
	25.2 Propellant Tank Conditions	386
	25.3 Stage Systems Performance	388
	25.4 Vehicle Forces and Motions	389

APPENDICES

1.	MASS CHARACTERISTICS (WS11)	411
2.	ENGINE PERFORMANCE PROGRAM (AA89)	429
3.	ENGINE PERFORMANCE PROGRAM (F823)	433
4.	FLOWMETER RECONSTRUCTION (G105)	437
5.	ENGINE PERFORMANCE PROGRAM (PA49)	439
6.	FLIGHT SIMULATION DATA (AC77)	443
7.	OBSERVED TRAJECTORY (AA83)	465
8.	METEOROLOGICAL DATA (AA99)	477
9.	GLOSSARY AND ABBREVIATIONS	483

LIST OF TABLES

Table		Page
3-1	Saturn S-IVB-202 Stage and GSE Flight Orifices	19
3-2	S-IVB-202 Pressure Switches	21
4-1	Flight Sequence of Events	29
4-2	Ground Sequence of Events	53
5-1	APS Propellant Loaded	65
5-2	Launch System Pressurization Summary	66
5-3	Launch Engine Conditioning Summary	67
5-4	Terminal Countdown Sequence - S-IVB-202 Flight	68
6-1	AS-202 Conditions at Maximum Dynamic Pressure	73
6-2	AS-202 Conditions at S-IVB First Motion	74
6-3	AS-202 Trajectory Conditions	75
6-4	AS-202 Earth-Intersecting Conic Elements at Insertion	76
7-1	Mass Characteristics	90
8-1	Comparison of Computer Program Results	108
8-2	Predicted Propulsion System Performance Parameters vs Actual Values	109
8-3	Performance Comparison	110
8-4	Engine Sequence S-IVB-202 Flight	111
9-1	Ullage Rocket Performance - AS-202	143
9-2	Comparative Performance of Retrorockets	144
12-1	APS Propellant Consumption	186
13-1	S-IVB-202 Purge Function	197
14-1	Propellant Mass History	211
14-2	Engine Analysis Propellant Mass	212
14-3	Propellant Loading Summary	213
14-4	Propellant Residual Summary	214
14-5	Thrust Variations	215
15-1	S-IB/S-IVB Separation Sequence of Events	230
16-1	Instrumentation System Performance Summary	247
16-2	Instrumentation System Measurement Status	248

LIST OF TABLES (Continued)

Table		Page
16-3	Instrumentation System Measurement Details	250
16-4	RF and Antenna System Performance	253
19-1	Maximum Values of Critical Parameters	271
19-2	APS Events Summary	272
20-1	Hydraulic System Performance Values	288
21-1	Maximum Measured Temperatures of Major Structural Assemblies Subject to Aerodynamic Heating	296
23-1	Composite Vibration and Acoustic Levels	311
24-1	Tabulated, Measured, and Postflight Simulated Data - S-IVB-202	361
24-2	Selected Component Temperatures	364
25-1	Vehicle Characteristics Used In Flight Simulation From RO +592 to RO +597 sec	395
25-2	Impulse Usage From RO +592 to RO +597 sec	395
25-3	APS Impulse Usage	396
25-4	Maximum S-IVB/IU Angular Deviations Due to Service Propulsion System Engine Plume Impingement	396
AP 1-1	Definitions for Mass Characteristics Computer Program WS11	413
AP 1-2	Mass Breakdown Summary	415
AP 1-3	Mass Characteristics Summary	425
AP 2-1	Engine Performance Program (AA89)	431
AP 3-1	Engine Performance Program (F823)	435
AP 4-1	Flowmeter Reconstruction Data (G105)	438
AP 5-1	Program PA49 Printout Symbols	440
AP 5-2	Engine Performance Program (PA49)	441
AP 6-1	Flight Simulation Data (AC77)	445
AP 6-2	Programs AC77 and AA83 Symbol Definitions	452
AP 7-1	Observed Trajectory Tabulation (AA83)	467
AP 8-1	Meteorological Data (AA99)	479
AP 8-2	Meteorological Data Table of Definitions	481
AP 9-1	Glossary and Abbreviations	484

LIST OF ILLUSTRATIONS

Figure		Page
Frontispiece - Saturn AS-202 Vehicle Liftoff		
3-1	Propulsion System Configuration and Instrumentation	23
3-2	Propulsion Major Components Locations	25
3-3	Facility Propellant and Pneumatic Loading Systems	26
6-1	Trajectory Profile and Trace	77
6-2	S-IB Stage Flight Earth-Fixed Velocity Vector Elevation Histories	78
6-3	S-IB Stage Flight Axial Acceleration History	79
6-4	Dynamic Pressure and Mach Number Histories	80
6-5	Pitch and Yaw Angle of Attack Histories	81
6-6	Wind Speed and Azimuth Profile	82
6-7	S-IVB Stage Flight Inertial Velocity and Axial Acceleration History	83
6-8	S-IVB Stage Inertial Velocity Vector Elevation Angle and Azimuth Angle	84
6-9	S-IVB Stage Flight Crossrange Position and Velocity Histories	85
6-10	Inertial Velocity and Altitude Difference Histories	86
6-11	Range and Crossrange Difference Histories	87
6-12	Inertial Velocity Vector Elevation Angle and Azimuth Angle Difference	88
7-1	S-IVB-202 Flight Stage Best Estimate Mass	91
7-2	S-IVB-202 Flight Stage Mass and Center of Gravity	92
7-3	S-IVB-202 Flight Stage Mass and Moment of Inertia	93
8-1	J-2 Engine System and Instrumentation	117
8-2	LH2 Pump Performance During Engine Start	118
8-3	Thrust Chamber Temperature Profile	119
8-4	Engine Start and Control Sphere Performance	120
8-5	J-2 Engine Chamber Pressure	121
8-6	J-2 Engine Injector Supply Conditions	122
8-7	PU Valve Operation	123
8-8	Turbine Inlet Operating Conditions	124

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
8-9	J-2 Engine Pump Operating Conditions	125
8-10	Engine Steady State Performance	126
8-11	Engine Start Transient Characteristics	128
8-12	Engine LOX System Start Transient	129
8-13	Engine Cutoff Transient Characteristics	130
8-14	Total Accumulated Impulse After Engine Cutoff Command	131
8-15	Engine Start Sequence	132
8-16	Gas Generator Performance	133
8-17	AS-202 Flight Simulation Residuals (Actual Minus Simulated)	134
8-18	Predicted and Simulated Propulsion Parameters	135
9-1	Ullage Rocket Performance	145
9-2	Retrorocket Performance	146
10-1	LOX Tank Pressurization System	155
10-2	LOX Tank Conditions During Prepressurization and Boost	156
10-3	LOX Tank Pressurization System Performance	157
10-4	Cold Helium Supply	158
10-5	J-2 Heat Exchanger Performance	159
10-6	LOX Pump Chilldown System Performance	160
10-7	LOX Pump Chilldown System Operation	161
10-8	LOX Supply System	162
10-9	LOX Pump Inlet Conditions	163
10-10	LOX Pump Inlet Conditions During Firing	164
11-1	LH2 Tank Pressurization System	173
11-2	LH2 Tank Prepressurization System Performance	174
11-3	LH2 Tank Pressurization	175
11-4	LH2 Pump Chilldown	176
11-5	LH2 Pump Chilldown Characteristics	177
11-6	LH2 Supply System	178
11-7	LH2 Pump Inlet Conditions	179
11-8	LH2 Pump Inlet Conditions During Firing	180

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
12-1	Auxiliary Propulsion System and Instrumentation	187
12-2	APS Module No. 1 and No. 2 Bellows Extension	188
12-3	APS Module No. 1 and No. 2 Propellant Quantity	189
12-4	APS Module No. 1 and No. 2 Temperatures	190
12-5	APS Module Total Impulse	191
13-1	Pneumatic Control and Purge System	199
13-2	Pneumatic Control and Purge System Performance	200
14-1	LOX Mass Sensor Flight Non-Linearity	217
14-2	LH2 Mass Sensor Flight Non-Linearity	218
14-3	LOX Indicated PU Mass Correction	219
14-4	LH2 Indicated PU Mass Correction	220
14-5	PU Valve Position	221
14-6	S-IVB-202 LH2 and LOX Sensor Mass Error	222
14-7	S-IVB-202 LOX and LH2 Sensor Capacitance Error	223
14-8	PU Error Signal and Valve Response	224
14-9	Comparison of Predicted and Actual Thrust Histories	225
14-10	Thrust Response to PU Valve Position	226
15-1	S-IB/S-IVB Separation History	231
15-2	S-IB/S-IVB Relative Velocity History	232
15-3	S-IB/S-IVB Separation Longitudinal Acceleration	233
15-4	S-IB/S-IVB Separation, S-IB Pitch, Yaw, and Roll Angular Velocity	234
15-5	Probability of Lateral Displacement Exceeding a Specified Value	235
15-6	S-IB/S-IVB Separation Distance	236
15-7	S-IB/S-IVB Separation, S-IB Yaw Angular Velocity	237
15-8	S-IB Roll Rate Actual and Reconstructed	238
15-9	Retrorocket Positions	239
17-1	Forward Battery No. 1 and No. 2 Performance	259
17-2	Aft Battery No. 1 and No. 2 Performance	260
19-1	S-IVB Attitude Errors Powered Flight	273
19-2	Angular Rate Gyros S-IVB Power Flight	274

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
19-3	Actuator Positions During S-IVB Powered Flight	275
19-4	S-IVB/202 Attitude Errors at S-IB/S-IVB Separation	276
19-5	S-IVB/202 Attitude Rates at S-IB/S-IVB Separation	277
19-6	Recorded and Simulated Actuator Position During Guidance Initiation	278
19-7	Pitch Transient Following Guidance Staging and Introduction to Chi Tilde ($\tilde{\chi}$) Guidance Mode	279
19-8	Pitch Rate Transient Following Guidance Staging and Introduction of Chi Tilde ($\tilde{\chi}$) Guidance Mode	280
19-9	Auxiliary Attitude Control System and Vent Orientation	281
19-10	APS Firing History During S-IVB Powered Flight	282
19-11	Total Roll Impulse for S-IVB-202 Powered Flight	283
19-12	LOX and LH2 Slosh Frequency	284
19-13	S-IVB-202 LH2 Slosh Amplitudes	285
19-14	LOX Slosh Amplitudes	286
20-1	Hydraulic System Temperature and Reservoir Level	289
20-2	Pitch and Yaw Actuator Position	290
21-1	Axial Strain vs Flight Time, AS-202 Stage - Aft Skirt Sta 1196	297
21-2	Axial Strain vs Flight Time, AS-202 Stage - Aft Skirt Sta 1260	298
21-3	S-IB/S-IVB-202 Flight Axial Load vs Time, Sta 1196 and 1260	299
21-4	S-IB/S-IVB-202 Flight Bending Moment vs Time, Sta 1196 and 1260	300
22-1	Forward Skirt Thermoconditioning System Fluid Temperature	303
23-1	Acoustic and Vibration Measured Locations	313
23-2	Low Frequency Vibration Measured at the LOX Turbopump, Lateral Direction (E0081-401)	314
23-3	Vibration Measured at the LOX Turbopump, Lateral Direction (E0082-401)	315
23-4	Low Frequency Vibration Measured at the LH2 Turbopump, Lateral Direction (E0083-401)	316
23-5	Vibration Measured at the LH2 Turbopump, Lateral Direction (E0084-401)	317

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
23-6	Vibration Measured on the Yaw Actuator Servo Valve, Axial Direction (E0175-403)	318
23-7	Vibration Measured on the Yaw Actuator Servo Valve, Radial Direction (E0176-403)	319
23-8	Vibration Measured on the Yaw Actuator Servo Valve, Tangential Direction (E0177-403)	320
23-9	Vibration Measured on the Pitch Actuator Servo Valve, Axial Direction (E180-403)	321
23-10	Vibration Measured on the Pitch Actuator Servo Valve, Radial Direction (E0178-403)	322
23-11	Vibration Measured on the Pitch Actuator Servo Valve, Tangential Direction (E0179-403)	323
23-12	Vibration Measured on the Gimbal Block, Thrust Direction (E0087-403)	324
23-13	Vibration Measured on the Gimbal Block, Pitch Direction (E0088-403)	325
23-14	Vibration Measured on the Gimbal Block, Yaw Direction (E0089-403)	326
23-15	Vibration Measured on the Yaw Actuator Attach Point, Axial Direction (E0021-403)	327
23-16	Vibration Measured on the Pitch Actuator Attach Point, Axial Direction (E0020-403)	328
23-17	Vibration Measured at the Input to the Sequencer Panel, Thrust Direction (E0011-404)	329
23-18	Vibration Measured at the Input to the Sequencer Panel, Radial Direction (E0012-404)	330
23-19	Vibration Measured at the Input to the Sequencer Panel, Tangential Direction (E0013-404)	331
23-20	Vibration Measured at the Input to the Switch Selector Panel, Thrust Direction (E0014-404)	332
23-21	Vibration Measured at the Input to the Switch Selector Panel, Radial Direction (E0016-404)	333
23-22	Vibration Measured at the Input to the Switch Selector Unit, Radial Direction (E0015-404)	334
23-23	Vibration Measured at the Input to the PU Electronic Panel, Thrust Direction (E0005-411)	335
23-24	Vibration Measured at the Input to the PU Electronic Panel, Radial Direction (E0007-411)	336

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
23-25	Vibration Measured at the PU Electronic Assembly, Radial Direction (E0006-411)	337
23-26	Vibration Measured at the Input to the Telemetry Rack, Thrust Direction (E0008-411)	338
23-27	Vibration Measured at the Input to the Telemetry Rack, Radial Direction (E0009-411)	339
23-28	Vibration Measured at the Input to the Telemetry Rack, Tangential Direction (E0010-411)	340
23-29	Vibration Measured on the Field Splice, Thrust Direction (E0017-411)	341
23-30	Low Frequency Vibration Measured on Field Splice, Thrust Direction (E0085-411)	342
23-31	Vibration Measured on the Field Splice, Radial Direction (E0018-411)	343
23-32	Low Frequency Vibration Measured on the Field Splice, Radial Direction (E0086-411)	344
23-33	Vibration Measured on the Field Splice, Tangential Direction (E0019-411)	345
23-34	External Sound Pressure Levels Measured on the Forward Skirt	346
23-35	Internal Sound Pressure Levels Measured in the Forward Skirt	347
24-1	Aero/Thermodynamics S-IVB-202 Instrumentation	365
24-2	Forward Skirt Skin and Stringer Temperature at DAC Sta 671	366
24-3	Forward Skirt Skin and Stringer Temperature at DAC Sta 671	367
24-4	LH2 Tank Skin Temperature	368
24-5	Aft Skirt Skin Temperatures	369
24-6	Aft Interstage Skin Temperature	372
24-7	Protuberance Temperature	373
24-8	Gas Probe and Thrust Structure Temperature	374
24-9	Base Region and J-2 Engine Calorimeters	375
24-10	Aft Interstage and Aft Skirt Heat Flux	376
24-11	Longitudinal Temperature Profile	377
24-12	Forward and Aft Skirts Internal Pressure Relative to Ambient	378

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
24-13	Forward Skirt, Aft Skirt, and Interstage Differential Pressures	379
24-14	Force History on S-IVB Stage Due to Retrorocket Plume Impingement	381
24-15	Total LH2 Propellant Heating	383
25-1	LOX and LH2 Tank Ullage and Common Bulk Differential Pressures	397
25-2	LOX and LH2 Tank Temperature	398
25-3	Pneumatic Control Sphere Conditions During Coast	399
25-4	Cold Helium Sphere Conditions During Coast	400
25-5	Attitude Errors and Rates Following S-IVB Cutoff	401
25-6	Auxiliary Propulsion System Firing History Following S-IVB Cutoff	402
25-7	Total Auxiliary Propulsion System Impulse for S-IVB/202 Coast Phase	405
25-8	Pitch Attitude Errors and Rates Following S-IVB Cutoff	406
25-9	Yaw Attitude Errors and Rates Following S-IVB Cutoff	407
25-10	Roll Attitude Errors and Rates Following S-IVB Cutoff	408
25-11	Estimated SC Engine Plume Impingement Disturbance on S-IVB-202 During Orbital Coast	409
AP 1-1	Saturn S-IVB/IB Installation - Station List Saturn AS-202 Vehicle Liftoff	427

1. INTRODUCTION

1.1 General

This report presents the results of analyses that were performed by DAC personnel on the countdown, launch, and flight of the Saturn S-IVB-202 stage.

Also described are tests conducted at Kennedy Space Center (KSC), and pertinent modifications made to the S-IVB stage and related ground support equipment.

This report is authorized by NASA Contract NAS7-101 and is the final report on the 202 stage by the DAC Test Planning and Evaluation Committee of the Systems Space Center (SSC), Huntington Beach, California.

1.2 History

The S-IVB-202 stage was assembled and its systems were checked-out at SSC before it was shipped to Sacramento Test Center (STC). It arrived there on 1 September 1965 and underwent a full-duration acceptance firing on 1 December 1965. Its two auxiliary propulsion modules, shipped from the DAC facility in Santa Monica, were confidence-fired in STC Gamma Complex test cell 2.

During these tests, all stage and module test objectives presented in DAC Report No. SM-46802, Saturn S-IVB-202 Stage Acceptance Firing Test Plan, were satisfactorily completed and the integrity of the stage and its systems was verified.

On 15 January 1966, the stage was shipped to KSC where it was erected on complex 34, and on 25 August 1966, it was launched as the second stage of the AS-202 vehicle. After successfully completing its mission objectives it was deliberately tested to destruction during the common bulkhead test.

Destruction of the S-IVB stage and loss of signal occurred 15 min 41 sec after liftoff.

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2. SUMMARY

The S-IVB-202 stage, launched on 25 August 1966 as the second stage of the Saturn AS-202 vehicle, satisfactorily accomplished all its flight objectives. Launch was made from Kennedy Space Center (KSC) complex 34 on a sub-orbital, re-entry trajectory. The payload for AS-202 was an Apollo spacecraft consisting of a command module, a service module, a lunar excursion module adapter section, and a launch escape system. An LEM was not included.

The S-IVB, along with its associated ground support equipment, performed as expected during the countdown and launch with this exception: during S-IVB LOX loading, the LOX chilldown pump motor container purge pressure decreased to ambient. After 1 hr 15 min the pressure returned to normal. This performance was attributed to a helium seal leak and had no adverse effects on LOX loading or the progress of the countdown.

The S-IVB stage systems performed satisfactorily during launch and first stage powered flight. S-IB/S-IVB separation was accomplished satisfactorily and J-2 engine ignition transients were as expected. S-IVB powered flight was nominal. SPS engine plume impingement on the S-IVB vehicle affected many of the S-IVB systems following S-IVB/CSM separation.

The S-IVB mission was concluded with the common bulkhead test during the coast phase which resulted in the destruction of the stage.

Two anomalies significant to the S-IVB stage were observed during the flight. They were identified as follows:

a. The LH2 recirculation shutoff valve failed to fully close prior to Engine Start Command but had no detrimental effect on stage performance

b. One retrorocket experienced a case burn through during S-IB/S-IVB separation. This anomaly did not adversely affect stage separation.

2.1 Countdown Operations

The countdown proceeded satisfactorily without major problems, although four holds were called for various reasons. All preparations and loading operations were satisfactorily completed. A brief problem with the LOX chilldown pump motor container purge occurred during LOX loading, but was satisfactorily corrected. The terminal countdown was interrupted to replenish S-IB stage fuel. This operation was satisfactorily completed and liftoff occurred at 1715:32.96 GMT.

2.2 Trajectory

The AS-202 actual trajectory was close to that predicted and well within stage design trajectory conditions.

A comparison of actual versus predicted trajectory indicated that at S-IVB stage first motion, the vehicle had achieved 1,700 ft longer range, 77.9 ft/sec greater velocity, and 8,606 ft higher altitude, with a burntime of 1.15 sec less than predicted. The conditions at S-IVB stage engine cutoff were close to those predicted. The following tables present significant trajectory parameters at S-IB/S-IVB separation and S-IVB cutoff.

Trajectory Parameters at S-IVB Stage First Motion

Parameter	Units	Actual	Deviation*
Range time	sec	144.33	-1.15
Relative velocity	ft/sec	6,165.4	+77.9
Altitude	ft	193,852	+8,606
Range	ft	188,790	+1,700
Crossrange velocity	ft/sec	-27.5	-36.1

* Deviation is actual minus predicted

Trajectory Parameters at S-IVB Stage Engine Cutoff

Parameter	Units	Actual	Deviation*
Range time	sec	588.47	-13.05
Inertial velocity	ft/sec	22,310.6	0.8
Altitude	ft	712,710	-101
Range	ft	5,107,567	-125,724
Crossrange velocity	ft/sec	659.4	-4.7
Crossrange distance	ft	121,336	-4,228

* Deviation is actual minus predicted.

2.3 Mass Characteristics

The mass of the S-IVB-202 flight stage at Engine Start Command was 316,001 ±991 lbm and 82,625 ± 306 lbm at Engine Cutoff Command.

The mass at Engine Start Command was within 0.02 percent (+50 lbm) of the predicted mass, and 1.6 percent (+1,320 lbm) at Engine Cutoff Command.

The greater-than-predicted mass at engine cutoff is a direct result of the higher than predicted performance of both the S-IB and S-IVB stages.

2.4 J-2 Engine System

The J-2 engine, S/N J-2016, performed satisfactorily throughout the flight test. All components functioned satisfactorily, although the main LOX valve opening time was slightly slow. Engine performance was slightly higher than predicted and the PU valve cutback was later than predicted, contributing to a total short S-IVB burntime of 13.05 sec.

2.5 Solid Rockets

The ullage rockets performed satisfactorily. They ignited properly on command and were successfully jettisoned. Stage propellants were satisfactorily settled for J-2 engine ignition. The four S-IB retrorockets satisfactorily fulfilled their function, although one motor suffered an apparent case burn-through.

2.6 Oxidizer System

The oxidizer system met all design criteria throughout S-IVB powered flight. The stage LOX tank pressurization system maintained the ullage pressure between 37.8 and 40.2 psia throughout flight. Engine pump chilldown was satisfactorily accomplished and the engine pump inlet conditions were within the required limits throughout the flight.

2.7 Fuel System

The fuel system provided satisfactory conditions throughout the flight, with tank pressure being maintained above 28.8 psia. The pressurization system performed well and with the modified inlet diffuser, there was no severe pressurant collapse during the flight. Pump chilldown and engine supply were satisfactory, although the recirculation shutoff valve again failed to close.

2.8 Auxiliary Propulsion System

The auxiliary propulsion system functioned properly providing adequate impulse to control S-IVB attitude during powered flight, separation, and sub-orbital coast.

2.9 Pneumatic Control and Purge System

The pneumatic control and purge system performed satisfactorily throughout the S-IB boost and S-IVB engine operation, although some trouble was experienced with the LOX chilldown pump motor container purge during the countdown. The helium supply to the system was adequate for both pneumatic valve control and purging, and the regulator pressure was maintained within acceptable limits. All components functioned normally. A high helium usage rate was experienced during the period after engine cutoff when the LOX tank vent and prevalves were being actuated.

2.10 Propellant Utilization

The PU System accomplished all of its design objectives for loading and PU control. The PU System indicated load was within -0.07 percent LOX and +0.27 percent LH2 of the actual loads as determined by the best estimate method. PU valve cutback occurred 24.1 sec later than predicted, but was well within the $\pm$45 sec tolerance.

2.11 S-IB/S-IVB Separation

Separation of the S-IVB stage from the S-IB stage was accomplished satisfactorily within the desired time period. First axial motion between the stages occurred 0.06 sec after Separation Command. Complete separation was accomplished 1.03 sec after Separation Command. Lateral motion utilized 5.8 in. of the 83 in. available lateral clearance.

2.12 Data Acquisition System

Data acquisition system performance was excellent. Two of 435 measurements active for flight failed to provide usable data during the time of interest. Measurement efficiency was 99.54 percent. Inflight tape recorder performance was satisfactory providing good quality separation data.

Three measurement problems occurred at RO +610 sec. SPS engine plume impingement or particle impact are considered possible contributing factors to these problems. From an instrumentation system design point of view there were no measurement failures during the flight. System design performance is summarized as follows:

Measurements assigned	472
Measurements inoperative due to stage configuration	-2
Checkout measurements	-19
Measurements monitored by S-IB stage	-6
Measurements failing prior to automatic sequence	-2
Measurements deleted prior to countdown	-8
Measurements active for flight	435
Measurement failures	None

2.13 Electrical System

The electrical control system and electrical power system performed as required. All control signals were distributed as required and proper receipt of talkbacks verified correct response of the subsystems. The S-IVB stage responded to 56 switch selector commands throughout flight. All power supplies operated within their design tolerances. The exploding

bridgewire subsystems for ullage rocket ignition, stage separation, retrorocket ignition and ullage rocket jettison all charged and fired properly upon command.

2.14 Range Safety System

The range safety system was not required for propellant dispersion during the flight. All indications showed that the system was operating properly and capable of performing satisfactorily had it been required. Received signal strengths were above threshold until the Safe Command was given at RO +590.697 sec.

2.15 Flight Control

Main engine control system performance during the S-IVB stage powered flight was satisfactory. The transients at separation, guidance initiation, guidance staging and introduction of $\tilde{\chi}$ guidance mode were well within the capabilities of the system. The observed LH2 sloshing was lower in magnitude than that seen on AS-201 and had no significant effect on control system performance. The auxiliary attitude control system performed satisfactorily for roll stabilization during S-IVB powered flight, and for vehicle pitch, yaw, and roll attitude control following S-IVB engine cutoff. The steady-state roll torque experienced during powered flight, was approximately 20 ft-lbf as compared to the 100 ft-lbf torque upon which the APS propellant is allocated.

2.16 Hydraulic System

The hydraulic system performed satisfactorily throughout flight. All pressure, temperature, oil level, actuator position, and flowrate values were as expected. As in previous flights, bias signals from the instrument unit were applied to the S-IVB pitch and yaw servo actuators resulting in a displacement of +0.2 and -0.8 deg, respectively, during S-IB powered flight and the coast phase. These signals were not present during J-2 engine burn and therefore did not result in any performance problems.

2.17 Stage Structure and Environment

The structural integrity of the S-IVB-202 stage was maintained throughout the flight. The flight conditions imposed on the S-IVB stage were less than the design values. At inboard engine cutoff, the measured axial acceleration was 2 percent less than the design limit axial acceleration. The S-IVB stage body bending moments were considerably less than the maximum predicted values because of the small wind shears and gusts encountered during first stage powered flight. All exploding bridgewire initiated ordnance systems performed as required. The failure test of the common bulkhead at high altitude conditions gave results as predicted.

2.18 Forward Skirt Thermoconditioning System

The forward skirt thermoconditioning system operated satisfactorily throughout the boost phase. The data indicates that the system supplied heat to the electronic equipment mounted on the cold plates for the majority of the first 110 sec of flight and received heat from the equipment the remainder of the flight. After approximately RO +350 sec, the average increase in the temperature of the coolant fluid from inlet to outlet was 2 deg F.

2.19 Acoustic and Vibration Environment

A total of 38 acoustic and vibration measurements were monitored on the S-IVB-202 stage. All measurements provided usable data.

In general, the dynamic environment during this flight was comparable to the AS-201 flight. Vibration transients were noted after S-IVB engine cutoff due to the S-IVB/spacecraft separation and the plume impingement from the service propulsion system firing. The measured levels were lower than those during powered flight.

2.20 Aero/Thermodynamic Environment

All of the objectives of the aero/thermodynamic measurements were achieved.

Structural temperatures were as expected and well within the design limits of the stage. A maximum sensor temperature of 649 deg R corresponding to an estimated maximum structural temperature of 703 deg R occurred on the forward skirt.

The magnitude of retrorocket heating effects during stage separation was similar to that previously observed for S-IVB-201. The aft interstage insulation system performed satisfactorily in this environment. Resulting temperatures were within design limitations.

Evaluation of flight data yielded forward skirt, aft skirt and interstage maximum and minimum pressure differentials which were within the predicted maximum and minimum design envelope.

Liquid hydrogen heating, from prepressurization throughout powered flight, fell within the predicted design values.

No significant component thermal problem areas were apparent during the S-IVB-202 flight.

2.21 Sub-Orbital Coast Phase

During the coast phase, the auxiliary attitude control system performed all required maneuvers and maintained attitude control even under the greater than expected moments generated by the SPS plume impingement.

The bulkhead test proved that the common bulkhead can withstand an operation operational malfunction of the LOX tank vent system within the limits of the LH2 tank relief valve for prescribed time periods. It also proved the structural capability of the common bulkhead to withstand the maximum ultimate design reverse differential pressure for a prelaunch malfunction condition.

3. CONFIGURATION

This section briefly describes the configuration of the S-IVB-202 flight stage and presents pertinent stage and vehicle support equipment modifications. Details of specific system modifications are discussed in the appropriate sections of this report.

3.1 Stage Configuration

The general configuration of the S-IVB-202 stage is described in DAC Report No. SM-46975, S-IVB-202 Stage Flight Test Plan, and additional stage information may be found in the documents listed below.

a. DAC Report No. SM-46802, Saturn S-IVB-202 Stage Acceptance Firing Test Plan, dated September 1965.

b. DAC Report No. SM-37524, Saturn S-IVB-202 Stage Acceptance Firing 15-Day Report Sacramento Test Center, dated December 1965.

c. Drawing No. 1B57803, S-IVB-202 Stage End Item Test Plan, dated January 1966.

d. DAC Report No. SM-47465, Narrative End Item Report on Saturn S-IVB/IB-202 (DAC S/N 2002), dated February 1966.

e. DAC Report No. SM-47184, Saturn S-IVB/IB Range Safety Report, dated 27 May 1966.

f. DAC Drawing No. 1B43555, Instrumentation Program and Components List, Saturn S-IVB-202.

g. DAC Report No. SM-47468, Saturn S-IVB-202 Stage Acceptance Firing Report, dated January 1966.

The S-IVB-202 stage was launched with the propulsion system installation configuration presented in figure 3-1. Also shown is a parts list of propulsion system components with orifice sizes, nominal pressure switch settings, and nominal regulator settings. Additional propulsion system orifice characteristics and pressure switch checkout data are presented in tables 3-1 and 3-2. Serial numbers and positions of the J-2 engine, the four retrorockets, three ullage rockets, and the two auxiliary propulsion system modules are shown in figure 3-2. Facility propellant and pneumatic loading systems are shown in figure 3-3. Serial numbers of significant end items are as follows:

End Item	Part Number	Serial Number
Engine driven hydraulic pump	1A66240-501	MX109713
Auxiliary hydraulic pump	1A66241-503	X454597
PU electronics assembly	1A59358-511	00001
Inverter-converter assembly	1A66212-501	00006
Chilldown inverters	1A74039-505	00025
		00010
Tape recorder	1A66884-501	009
Telemetry transmitter		
CF1	1A58842-501	045
CF2	1A58842-505	059
CF3	1A58842-1	046
CP1	1A58842-503	033
CS1	1A58842-507	050
Telemetry power amplifier		
CF1	1A77080-501	16
CF2	1A77080-505	42
CF3	1A77080-1	10
CP1	1A77080-503	25
CS1	1A77080-507	39
Range safety command receiver		
No. 1	50M10697	127
No. 2	50M10697	21
Safe and arm device	1A02446-503	00005
Ullage rocket		
I-II	1A81960-1	K786-2
III-II	1A81960-1	K786-4

End Item	Part Number	Serial Number
IV-I	1A81960-1	K786-5
LOX fill and drain valve	1A48240-501	0020
LH2 fill and drain valve	1A48240-501	0021
tank probe		
LOX	1A48430-501	E5
LH2	1A48431-501	E7
LOX vent and relief valve	1A48312-503	0021
LH2 vent and relief valve	1A48257-1	0010
Directional control valve	1A49988-1	0003
LOX relief valve	1A49590-507	516
LH2 relief valve	1A49591-513	135
LOX tank chilldown pump	1A49423-503	X-1379
LH2 tank chilldown pump	1B37129-1	X-1359
LOX prevalve	1A49968-509	006
LH2 prevalve	1A49968-507	005
APS module No. 1	1A39597-1	
Engine 1-1 (I-IV)		548
Engine 1-2 (I-P)		543
Engine 1-3 (I-II)		558
APS module No. 2	1A39597-1	
Engine 2-1 (III-II)		583
Engine 2-2 (III-P)		547
Engine 2-3 (III-IV)		541
Aft 1 battery	1A83470-505	18
Aft 2 battery	1A83471-503	22

End Item	Part Number	Serial Number
Fwd 1 battery	1A83468-505	22
Fwd 2 battery	1A83469-503	19

3.2 Stage Modifications

The following significant measurement changes and stage modifications were accomplished on the S-IVB-202 stage at Florida Test Center:

a. Measurement N0062-411, Misc-Secure Range Safety Receiver No. 2 Low Level Signal Strength, was added; measurement N0057-411, Misc-Secure Range Safety Receiver No. 1 Low Level Signal Strength, was reassigned from a 120 sps telemetry channel to a 12 sps telemetry channel in 270 multiplexer No. A-1. A new programmed sub-multiplexer board (P/N 1B59981-1) was installed in slot 22 of model 270 multiplexer, No. A-1 to replace a dummy board. (WRO S-IVB-A3/A41-265A, C/O 798)

b. Measurements K0098-411, Event-Range Safety No. 1 Arm Cutoff Destruct Indication, and K0099-411, Event-Range Safety No. 2 Arm Cutoff Destruct Indication, were rechanneled from 12 sps to 120 sps. (WRO S-IVB-A3/A41-242A, C/O 809)

c. These J-2 engine temperature measurements were changed: measurements C0148-401, Temperature-Gas Generator LH2 Bleed Valve Wall, and C0151-401, Temperature-Engine Oxidizer Pump Wall, were deleted. Measurements C2000-401, Temperature-Heat Flux Engine Nozzle No. 4, and C2005-401, Temperature-Engine Main LOX Valve Closing Control Pneumatic Line Surface, were added. (WRO S-IVB-A3/A41-496A)

d. Model II switch selector, P/N 50M67864-5, provided by NASA, was installed. Aluminized mylar tape was applied to the switch selector and the adjacent mounting area. (WRO S-IVB-A3/A41-328A, WRO S-IVB-A3/A41-225A R-2)

e. Two coats of Dynatherm, D-65 primer were applied to the J-2 engine manifold, P/N 557441, from the pneumatic regulator to the main oxidizer valve, to prevent serious variations in main oxidizer valve actuation time due to control gas temperature variations. (WRO-S-IVB-A3/A41-364A, C/O 827)

f. A redundant check valve, P/N 1B51361-1, was added to the auxiliary propulsion system (APS) helium supply line. (WRO S-IVB-A3/A41-374A R2)

g. LH2 pressurization diffuser, P/N 1A79382-1, was replaced with LH2 pressurization diffuser, P/N 1B65812-1, to reduce the gas velocity during pressurization. (WRO S-IVB-A3/A41-370A R-2)

h. An environmental shroud was designed, fabricated, and installed around panels 10 and 11 in the aft skirt to guide GN2 from the environmental control system distribution duct directly to the panels. (WRO S-IVB-A3/A41-432A)

i. Two range safety antennas were replaced with a -501 configuration to prevent antenna feed from becoming disengaged. (WRO S-IVB-A3/A41-350A)

j. Two 1/4-in. hazardous gas detection lines and their associated bracketry were installed from S-I interface to the aft interstage vents. (WRO S-IVB-A3/A41-331A R-3 C/O 830)

k. Six diode modules, P/N 1B39975-1, in the flight sequence and power distributor box were replaced with modules, P/N 1B39975-501; one diode module, P/N 1B54541-1, in the inverter-converter, was replaced with P/N 1B66308-1. (WRO S-IVB-A3/A41-2629 R-2)

l. Insulating disks, P/N 10M14508, glass reinforced epoxy, were installed in the safe and arm device, P/N 1A02446. (WRO S-IVB-A3/A41-2735)

m. The upper LH2 feed duct inner liner had numerous random depressions and was replaced. (WRO-S-IVB-A3/A41-2831)

n. To prevent the pressure oscillations that were experienced in the LOX tank pressure measurement during countdown demonstration test propellant off-loading, a LOX tank pressure sense line purge system was installed. It affected the three LOX ullage pressure transducers and pressure switches by biasing the LOX ullage pressure sensed by +1.0 psi.

o. Shims were installed under the mounting flanges of three hydraulic accumulator reservoir pressure transducers, P/N's 1B31356-501 and -1. (WRO S-IVB-A3/A41-2756)

p. PCM/DDAS assembly, P/N 1A74049-507, S/N 00003, vendor S/N 13028, was installed because the stage arrived at KSC without it. (WRO S-IVB-A3/A41-177A R-2)

q. Two propellant control modules, P/N 1A49422-506 and -505, one from each APS module, were replaced. (WRO S-IVB-A3/A41-972 R-2, WRO S-IVB-A3/A41-186A)

r. Doublers were installed in the LOX tank on seal welds. (1A74633-A41-2)

s. Auxiliary hydraulic pump, P/N 1A66241-501, S/N 454588, was removed and replaced by 1A66241-503, S/N 454597. The -503 pump incorporates a redesigned compensator spring and an improved gas seal. (WRO S-IVB/965)

t. Measurement K0115-401, Event-Sequence Control Valve Closed, was deleted. (WRO S-IVB-A3/A41-069A R-2)

u. Six - 7 configurated cable assemblies in the APS transducers, P/N 1A88035-1, were replaced with DAC-fabricated cable assemblies, P/N 1A81850-1-005. (WRO S-IVB-A3/A41-2823 R-1)

3.3 Ground Support Equipment

The following significant modifications were accomplished on ground support equipment.

3.3.1 Model 432 Console

a. The APS 0.027 orifice was relocated downstream of the 3,000 and 50 psi He APS supply valves in accordance with existing drawings.

b. The 1B37340-501 400 psi dome supply regulator was replaced with a 1B37340-509 regulator.

3.3.2 Model 433 Console

a. New shaft seals were installed on six cold valves. During rework of the valves the cold helium supply valve was found to have the poppet shaft galled to the actuator shaft; the supply valve was replaced.

The engine control bottle supply and supply vent valves leaked past the actuator. The valves were reworked and reinstalled.

b. A 2,500 psi GN2 purge with blockhouse control was installed directed at the cold valves.

3.3.3 Model 438 Console

a. New shaft seals were installed in eight cold valves. One cold valve, the LH2 tank purge valve, was removed from the system.

Circuit No. 1 vent valve had its poppet shaft galled to the actuator shaft; the valve was replaced.

The fuel tank prepress supply valve was contaminated by pieces of damaged omniseals as a result of reworking the cold valves. This valve was removed and replaced.

b. A 750 psi GN2 purge was installed on the cold valves.

c. Heat exchanger fill valve, P/N 7868452-511, was reworked to the 7868452-513 configuration.

d. Orifices were installed in circuit No. 1 vent and start tank supply vent lines. Following CDDT the 0.116 orifice was removed from the circuit No. 1 start tank supply line.

e. Leakage was noted at several Natorq fittings (4 filter and HEX circuits No.'s 1, 2 and 3 inlets). The Natorqs were removed and teflon O-rings were installed.

f. The 2-in. pressure operated "Y" valve, P/N 7864252 in cold gas generator, model DSV-4B-438, S/N 00001, was reworked. (WRO S-IVB-A3/A41-2592 R-1)

TABLE 3-1 (Sheet 1 of 2)
SATURN S-IVB-202 STAGE AND GSE FLIGHT ORIFICES

ITEM*	DESCRIPTION	ORIFICE SIZE OR NOMINAL FLOWRATE	COEFFICIENT OF DISCHARGE	EFFECTIVE AREA ($in.^2$)
	Stage			
15	LH2 Fill and Drain Valve Purge	15 scim at 3,200 psid	--	Sintered
21	LOX Fill and Drain Valve Purge	15 scim at 3,200 psid	--	Sintered
12	Control Helium Plenum Outlet Bleed	184 scim at 515 psid	--	Sintered
33	LOX Tank Pressurization Heat Exchanger Bypass	0.166 in. dia	0.88	0.0190
32	LOX Tank Pressurization Heat Exchanger Outlet Primary	0.196 in. dia	0.87	0.0263
36	LH2 Tank Pressurization Undercontrol	0.258 in. dia	0.83	0.0435
36	LH2 Tank Pressurization Overcontrol	0.196 in. dia	0.83	0.686
36	LH2 Tank Step Pressurization	0.360 in. dia	0.79	0.1451
38	LH2 Tank Nonpropulsive Vent Purge	1 scfm at 3,200 psid	--	Sintered
54	LOX Chilldown Pump Purge Module Inlet	950 $\pm$95 scim at 475 psig	--	Sintered
56	LOX Chilldown Pump Purge Module	0.025 in. dia	NC**	--
78	LH2 Chilldown Valve Purge	1 scfm	--	Sintered
81	LOX Tank Vent and Relief Valve Purge	65 scfm at 3,000 psid	--	Sintered
85	Engine Pump Purge Module	0.023 in. dia	0.88	0.000363
	Significant GSE			
	Start Tank Supply Vent	0.055 in. dia	--	--
	Start Tank Supply	OPEN	--	--
	Fuel Tank Prepressurization	--	--	0.0184
	APS Console Bleed Orifices	0.018 in. dia	--	--

*Indicates location on figures 3-1 and 3-3.
**Not calibrated.

TABLE 3-1 (Sheet 2 of 2)
SATURN S-IVB-202 STAGE AND GSE FLIGHT ORIFICES

ITEM	DESCRIPTION	ORIFICE SIZE OR NOMINAL FLOWRATE	COEFFICIENT OF DISCHARGE	EFFECTIVE AREA ($in.^2$)
	Control Stage Helium Orifice	--	--	0.0033
	Engine Control Supply	--	--	0.0103
	LOX Tank Prepressurization	--	--	0.0090

TABLE 3-2 (Sheet 1 of 2)
S-IVB-202 PRESSURE SWITCHES

NAME	PART NUMBER	DESIGN (psia)		ACCEPTANCE				PRELAUNCH (psia)	
				PREFIRING (psia)		POSTFIRING (psia)			
		PICKUP	DROPOUT	PICKUP	DROPOUT	PICKUP	DROPOUT	PICKUP	DROPOUT
LH2 Tank									
LH2 Minimum Liftoff - Ground Fill Valve Control & Prepress.	1A67003-501	37	32 min	36.7	33.3	37.2	33.2	36.6	32.7
S-IB Flight Control	7851860-511	31	28 min	30.9	28.9	30.9	28.6	30.5	28.5
LOX Tank									
Prepress. & Flight Control	7851847-533	40 max	37 min	39.8	37.7	39.9	37.9	39.5	37.3
LOX Ground Fill Valve Control	1A67011-501	40 $\pm$1	37 min	41.8	39.1	40.2	38.1	--	--
LOX Pressurization System									
LOX Tank Regulator Backup	7851830-509	465 $^{+10}_{-15}$	350 $^{+15}_{-10}$	461	355	462	356	463	352
Pneumatic Power System									
Regulator Backup - CD 614047	7851830-511	535 $^{+15}_{-10}$	450 $^{+15}_{-10}$	541	453	--	--	--	--
Regulator Backup - CD 614048		540 $^{+15}_{-10}$	415 $^{+15}_{-10}$	554	454	555	453	--	--

TABLE 3-2 (Sheet 2 of 2)
S-IVB-202 PRESSURE SWITCHES

NAME	PART NUMBER	DESIGN (psia)		ACCEPTANCE				PRELAUNCH (psia)	
				PREFIRING (psia)		POSTFIRING (psia)			
		PICKUP	DROPOUT	PICKUP	DROPOUT	PICKUP	DROPOUT	PICKUP	DROPOUT
Regulator Backup - Flight	7851830-521	585 ±15	475 ±25	--	--	--	--	610	495
Engine Purge	1A67002-501	130 max	105 min	124.8	109.8	122.9	107.9	123	110
LOX Chilldown Pump Motor Purge	7851847-515	53 max	49 min	52.9	50.3	52.9	50.5	52.1	49.6
J-2 Engine									
Mainstage OK No. 1	NA5-27302	500 ±15	*	--	--	--	--	512	439
Mainstage OK No. 2	NA5-27302	500 ±15	*	--	--	--	--	517	439

*Design pickup pressure minus 75 ±25 psia

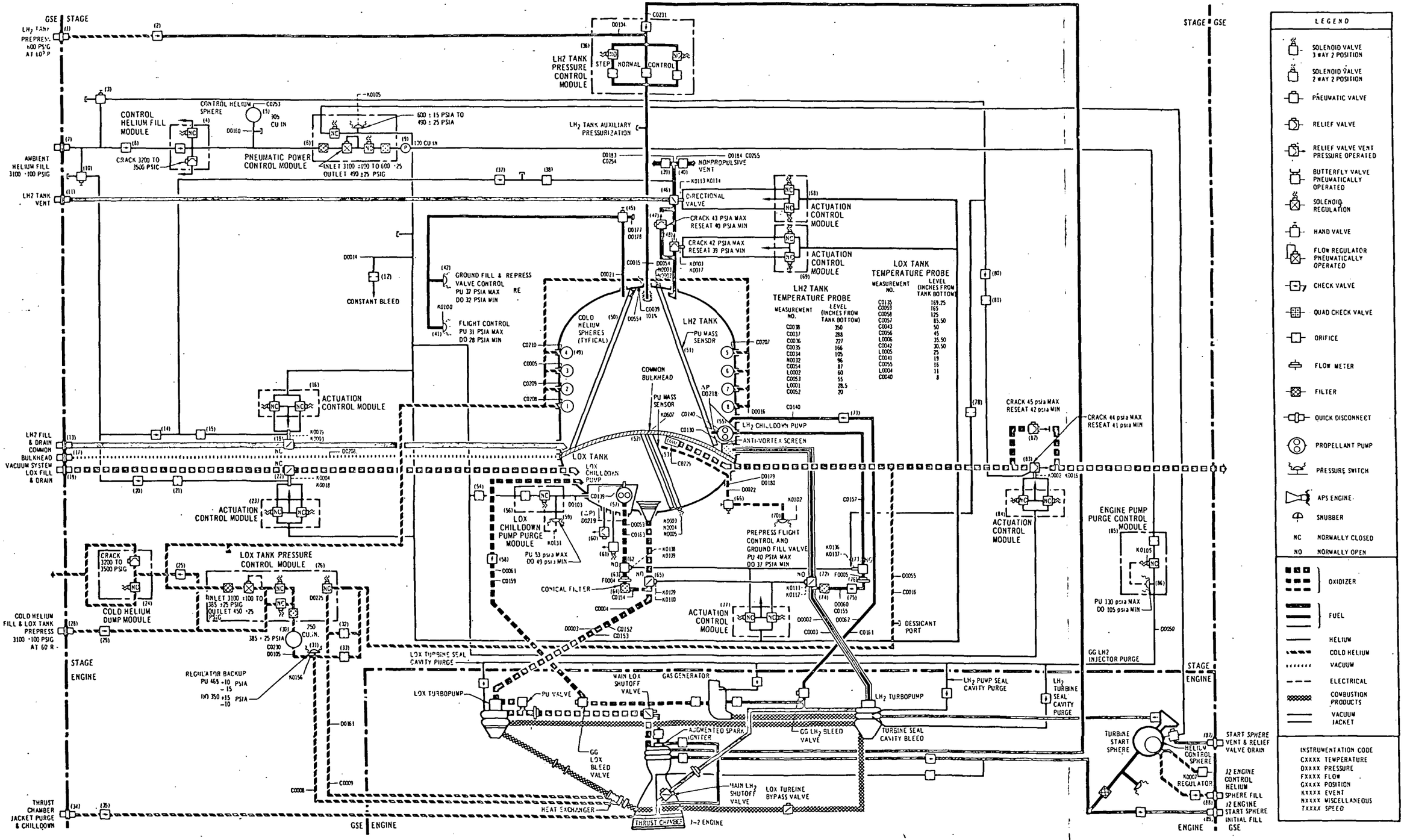

Figure 3-1. Propulsion System Configuration and Instrumentation (Sheet 1 of 2)
24 October 1966

FIND NO.	PART NO.	PART DESCRIPTION
1	7851861-1	Disconnect, LH2 tank pressurization
2	1A66984-1	Valve, check, LH2 prepressurization line
3	10414087	Valve, hand, 3-way, LOX tank vent and relief valve and sensing line and LH2 chilldown valve purge
4	1A57350-505	Module, control helium fill
5	1A49963-1	Sphere, control helium storage, 905 std cu in.
6	1B43657-507	Module, pneumatic power control
7	7851823-503	Disconnect, ambient helium fill
8	1B51361-1	Valve, check, ambient helium fill
9	1A48857-1	Plenum, control helium 100 std cu in.
10	10414087	Valve, hand, 3-way, prevalves, nonpropulsive vent and LH2 chilldown valve purge
11	1A48848-505	Disconnect, LH2 tank vent
12	1B40622-1	Orifice, bleed, control helium plenum outlet
13	1A49978-503	Disconnect, LH2 fill and drain
14	1B51361-1	Valve, check, LH2 fill and drain valve purge line
15	1B40622-505	Orifice, LH2 fill and drain valve purge line
16	1A49982-505	Module actuation control, LH2 fill and drain valve
17	1B41065-1	Disconnect, common bulkhead vacuum system
18	1A48240-501	Valve, LH2 fill and drain
19	1A49970-503	Disconnect, LOX fill and drain
20	1B51361-1	Valve, check, LOX fill and drain valve purge line
21	1B40622-505	Orifice, LOX fill and drain valve purge line
22	1B48240-501	Valve, LOX fill and drain
23	1A49982-505	Module, actuation control, LOX fill and drain valve
24	1B57781-1	Module, cold helium dump
25	1B40824-1	Valve, check, cold helium fill line
26	1B42290-503	Module, LOX tank pressure control
27	Deleted	
28	7851844-501	Disconnect, cold helium fill and LOX tank prepressurization
29	1B40824-1	Valve, check, cold helium fill and LOx prepressurization line
30	1A49991-1	Plenum, LOX tank pressurization, 250 std cu in.
31	7851830-509	Switch, pressure, LOX tank pressurization regulator backup, PU 465 +10, -15 psia, DO 350 +15, -10 psia
32	S0772C16-0.196	Orifice, LOX tank pressurization heat exchanger primary
33	S0772C12-0.161	Orifice, LOX tank pressurization heat exchanger bypass
34	1A49958-519	Disconnect, thrust chamber jacket purge and chilldown
35	1B51361-1	Valve, check, thrust chamber jacket purge line
36	1B55200-1	Module, LH2 tank pressure control
37	1B51361-1	Valve, check, LH2 nonpropulsive vent purge line
38	1B40622-501	Orifice, LH2 nonpropulsive vent purge line
39	1A89881-501	Orifice, nonpropulsive vent
40	1A89881-501	Orifice, nonpropulsive vent
41	7851860-539	Switch, pressure, LH2 flight control PU 31 psia, DO 28 psia
42	1A67003-501	Switch, pressure LH2 prepressurization and ground fill, PU 37 psia max, DO 32 psia min
43	N/A	Switch, pressure, LH2 tank orbital vent initiation, PU 35.5 ±7.5 psia, DO 32 psia min
44	N/A	Switch, pressure, orbital vent termination, PU 6.5 psia max, DO 1.5 ±0.5 psia
45	10414087	Valve, 3-way, LH2 tank pressure switch shutoff
46	1A49988-1	Valve, directional control, LH2 vent
47	1A49591-513	Valve, relief, LH2 tank, crack 43 psia max, reseat 40 psia
48	1A48257-1	Valve, vent and relief, LH2 tank, crack 42 psia max, reseat 39 psia min
49	1A48858-1	Sphere, cold helium (8 each)
50	N/A	Probe, LH2 temperature sensor
51	N/A	Probe, LH2 mass sensor
52	N/A	Probe, LOX temperature sensor
53	N/A	Probe, LOX mass sensor
54	1A48854-501	Orifice, LOX chilldown pump purge line
55	1B37129-1	Pump, LH2 chilldown
56	1A58347-505	Module, LOX chilldown pump purge
57	1A49423-503	Pump, LOX chilldown
58	1A49964-1	Valve, check, LOX chilldown return line
59	7851847-525	Switch, pressure, LOX chilldown pump purge, regulator backup, PU 53 psia max, DO 49 psia min
60	114-109 (PESCO)	Valve, relief, LOX chilldown pump motor container, crack and reseat 65 psia to 85 psia
61	1A67913-1	Valve, vent, LOX chilldown pump motor container
62	1A49965-509	Valve, shutoff, LOX chilldown pump discharge
63	1A89104-507	Flowmeter, LOX chilldown line
64	1A87749-1	Strainer, LOX chilldown pump discharge
65	1A49968-501	Prevalve, LOX
66	10414087	Valve, 3-way, LOX tank pressure switch shutoff
67	N/A	Switch, pressure, LOX tank orbital vent termination, PU 30 psia max, DO 25 psia min
68	1A49982-505	Module, actuation control, directional valve, LH2 vent
69	1A49982-507	Module, actuation control, LH2 vent and relief valve
70	7851847-533	Switch, LOX prepressurization, flight control and ground fill valve control, PU 40 psia max, DO 37 psia min
71	1A49964-1	Valve, check, LH2 chilldown return line
72	1A49968-503	Prevalve, LH2
73	1A49965-507	Valve, shutoff, LH2 chilldown pump discharge
74	1B52985-1	Strainer, LH2 chilldown pump discharge
75	1B53920-1	Valve, check LH2 chilldown pump discharge
76	1A89104-509	Flowmeter, LH2 chilldown line
77	1A49982-503	Module, actuation control, prevalves and chilldown valves
78	1B40622-507	Orifice, LH2 chilldown shutoff valve purge line
79	1B51361-1	Valve, check, LOX vent and relief valve purge line
80	DR 4-0.3	Orifice, LOX tank sensing line purge
81	S0268C4-04	Orifice, LOX vent and relief valve purge line
82	1A49590-507	Valve, relief, LOX tank, crack 45 psia, reseat 42 psia
83	1A48312-501	Valve, vent and relief, LOX tank, crack 44 psia, reseat 41 psia
84	1A49982-511	Module, actuation control, LOX vent and relief valve
85	1B56804-501	Module, engine purge control
86	1A67002-501	Switch, pressure, engine purge regulator backup
87	1A49958-521	Disconnect, engine start sphere vent and relief valve drain
88	1A49958-515	Disconnect, engine control helium sphere fill
89	1A49958-523	Disconnect, engine start sphere fill

Figure 3-1. Propulsion System Configuration and Instrumentation (Sheet 2 of 2)

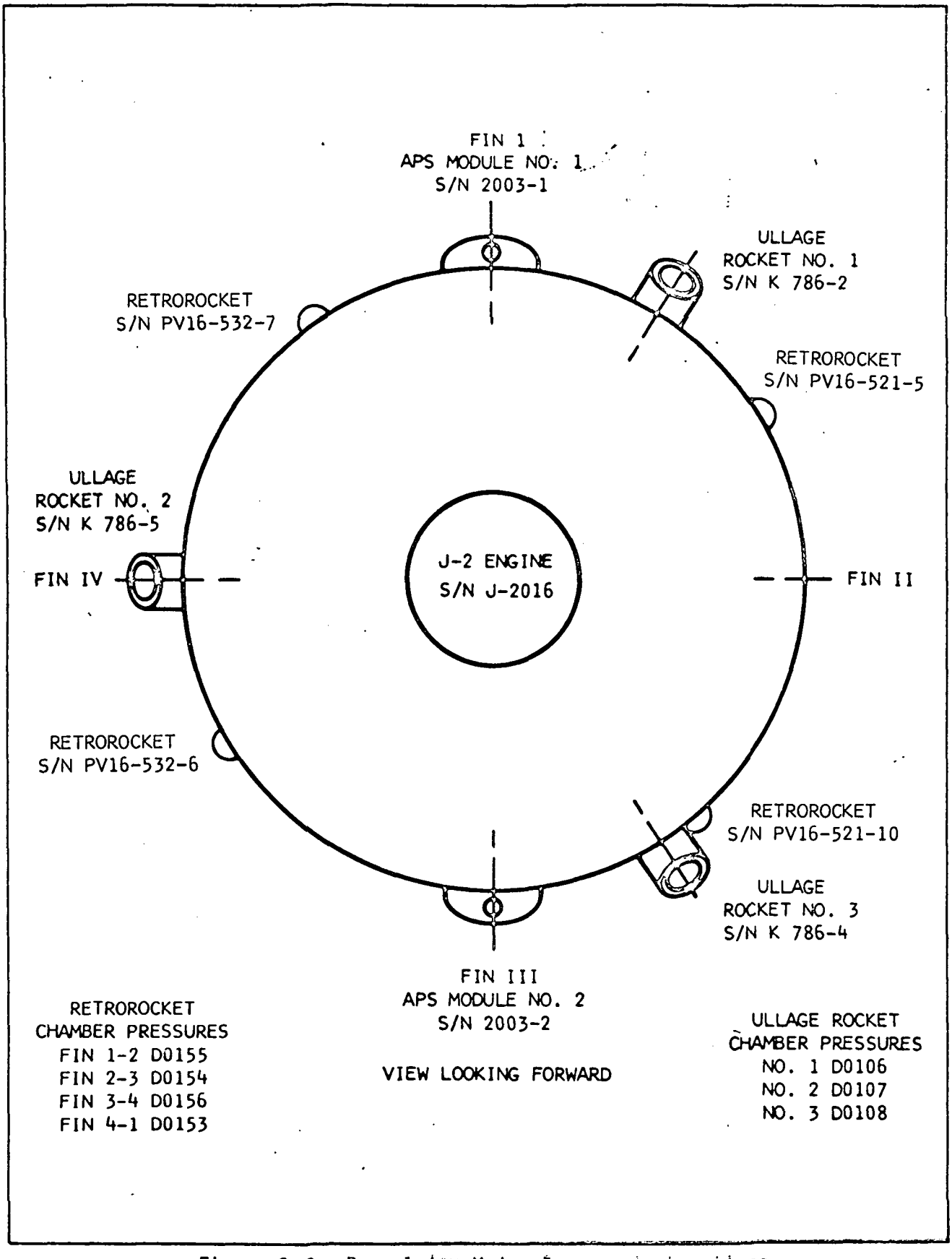

Figure 3-2. Propulsion Major Components Locations

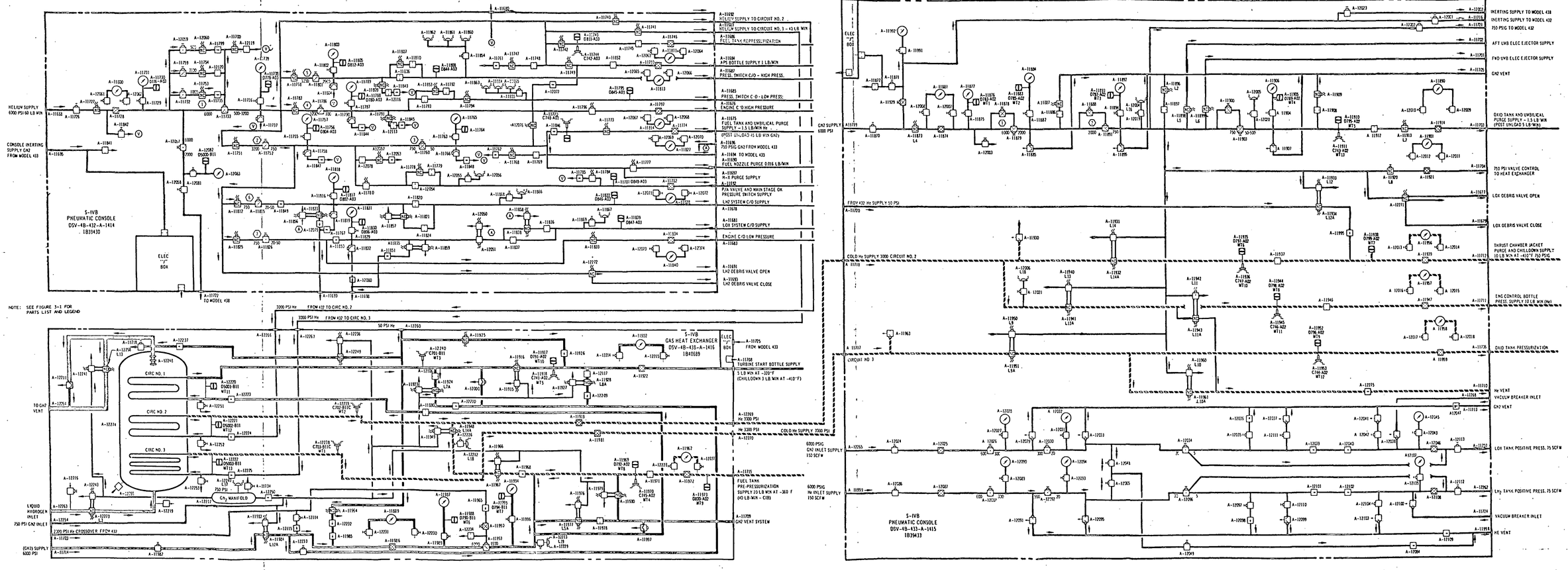

Figure 3-3. Facility Propellant and Pneumatic Loading Systems

24 October 1966

4. SEQUENCE OF EVENTS

Table 4-1 presents the AS-202 flight sequence of events. Three types of items are included in the sequence:

a. Commands - These items initiate from the launch vehicle digital computer (LVDC) in the instrument unit (IU) and direct vehicle system actions.

b. Events - These items are monitored occurrences resulting from vehicle performance such as the time of maximum dynamic pressure.

c. Responses - These items are responses to commands that are issued from the IU and are monitored in the S-IVB.

In the sequence, all commands and events are preceded by an item number. Responses to commands are listed under that command and are preceded by the command number followed by a lower case letter. The overall powered flight sequence was close to predicted and proper S-IVB response was given to all commands issued from the IU.

4.1 Predicted and Monitored Times

For most of the items in the sequence, both a predicted time and a monitored time are presented. The predicted times shown are adjusted to reflect the actual intervals between range zero (RO) and vehicle liftoff.

Commands issued from the LVDC to the S-IVB stage switch selector were generally monitored at both places. The monitored times from base are listed for commands monitored in the IU only. The times from base are not listed for events or responses.

The accuracies listed in table 4-1 are related to the telemetry-channel sampling rates; therefore, the items occurred at the times indicated or earlier by the amount listed in the accuracy column. For several items, the S-IVB responses were observed prior to issuance of commands from the IU. However, all discrepancies were within the accuracy to which the IU commands are determined. No other flight sequence discrepancies were observed.

4.2 Time Bases

The LVDC time bases during the AS-202 flight were as follows:

a. Time base one $(0)_1$ — IU umbilical disconnect

b. Time base two $(0)_2$ — S-IB stage level-sensor actuation

c. Time base three $(0)_3$ — S-IB stage outboard-engine cutoff

d. Time base four $(0)_4$ — S-IVB stage engine cutoff

4.3 Ground Sequence of Events

Table 4-2 presents the ground sequence of events from approximately RO -15 min to liftoff. These events are related to the S-IVB-202 stage and associated ground support equipment and are derived from the digital events evaluation (DEE). No out-of-sequence events or other anomalies occurred.

TABLE 4-1 (Sheet 1 of 24)
FLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME (sec)		SIGNAL MONITORED AT	MONITORED TIME (sec)		DATA SOURCE	ACCURACY (ms)
		TIME FROM RANGE ZERO	TIME FROM BASE		TIME FROM RANGE ZERO*	TIME FROM BASE		
1	Guidance Reference Release	- - -	- - -	IU	-3.535	N/A	MSFC	- - -
2	Range Zero	0.0	N/A	IU	0	N/A	MSFC	- - -
3	S-IB Engine Start	-2.3	$(-3.2)_1$	IU	-2.478	$(-3.411)_1$	MSFC	- - -
4	First Vertical Motion	0.73	N/A	GSE	0.73	N/A	MSFC	- - -
5	AS-202 Vehicle Liftoff IU Umbilical Disconnect (Start Time Base 1)	0.933	$(0.0)_1$	IU	0.933	$(0.00)_1$	MSFC	- - -
6	Signal From LVDC for: Auto Abort Relays Reset Command	5.9	$(5.0)_1$	IU	5.90	$(4.97)_1$	MSFC	- - -
7	Signal From LVDC for: Multiple Engine Cutoff Enable Command	10.9	$(10.0)_1$	S-IB	10.89	$(9.96)_1$	MSFC	- - -
8	Start Pitch Maneuver	10.9	N/A	IU	9.702	N/A	MSFC	- - -
9	Start Roll Maneuver	10.9	N/A	IU	9.702	N/A	MSFC	- - -
10	Stop Roll Maneuver	15.9	N/A	IU	14.70	N/A	MSFC	- - -
11	Signal From LVDC for: Tape Recorder Record On Command	39.9	$(39.0)_1$	IU	39.88	$(38.95)_1$	MSFC	- - -
12	Signal From LVDC for: Launch Vehicle Engines EDS Cutoff Enable Command	60.9	$(60.0)_1$	IU	60.88	$(59.95)_1$	MSFC	- - -
13	Maximum Dynamic Pressure	79.9	N/A	IU	79.5	N/A	MSFC	- - -
14	Signal From LVDC to Flight Control Computer for: Switch Point #1 Command	90.9	$(90.0)_1$	IU	90.90	$(89.97)_1$	MSFC	- - -

* Range Zero = 1715:32.0 (GMT)

TABLE 4-1 (Sheet 2 of 24)
FLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME (sec)		SIGNAL MONITORED AT	MONITORED TIME (sec)		DATA SOURCE	ACCURACY (ms)
		TIME FROM RANGE ZERO	TIME FROM BASE		TIME FROM RANGE ZERO*	TIME FROM BASE		
15	Signal From LVDC to Flight Control Computer For: Switch Point #2 Command	120.9	$(120.0)_1$	IU	120.88	$(119.96)_1$	MSFC	- - -
16	Signal From LVDC for: Control Accelerometer Power Off Command	121.1	$(120.2)_1$	IU	121.10	$(120.17)_1$	MSFC	- - -
17a	Signal From LVDC for: Special Calibration Relays On Command	128.4	$(127.5)_1$	IU	128.385	$(127.45)_1$	MSFC	- - -
17b	Signal Received In S-IVB for: Special Calibration Relays On Command	- - -	- - -	S-IVB	128.384	N/A	DAC (FM)	13
18a	Signal From LVDC for: Regular Calibration Relays On Command	128.6	$(127.7)_1$	IU	128.585	$(127.65)_1$	MSFC	- - -
18b	Signal Received In S-IVB for: Regular Calibration Relays On Command	- - -	- - -	S-IVB	128.584	- - -	DAC (FM)	13
19a	Signal From LVDC for: Regular Calibration Relays Off Command	133.0	$(132.1)_1$	IU	133.009	$(132.08)_1$	MSFC	- - -
19b	Signal Received In S-IVB for: Regular Calibration Relays Off Command	- - -	- - -	S-IVB	133.009	- - -	DAC (FM)	13
20a	Signal From LVDC for: Special Calibration Relays Off Command	133.2	$(132.3)_1$	IU	133.185	$(132.25)_1$	MSFC	- - -

* Range Zero = 1715:32.0 (GMT)

TABLE 4-1 (Sheet 3 of 24)
FLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME (sec)		SIGNAL MONITORED AT	MONITORED TIME (sec)		DATA SOURCE	ACCURACY (ms)
		TIME FROM RANGE ZERO	TIME FROM BASE		TIME FROM RANGE ZERO*	TIME FROM BASE		
20b	Signal Received In S-IVB for: Special Calibration Relays Off Command	- - -	- - -	S-IVB	133.182	- - -	DAC (FM)	13
21	Signal From LVDC for: Excessive Rate (Y, P or R) Auto-Abort Inhibit Enable Command	134.5	$(133.6)_1$	IU	134.48	$(133.55)_1$	MSFC	- - -
22	Signal From LVDC for: Excessive Rate (Y, P or R) Auto-Abort Inhibit Command	134.7	$(133.8)_1$	IU	134.68	$(133.75)_1$	MSFC	- - -
23	Signal From LVDC for: S-IB Engine Out Auto-Abort Inhibit Enable Command	134.9	$(134.0)_1$	IU	134.88	$(133.95)_1$	MSFC	- - -
24	Signal From LVDC for: S-IB Engine Out Auto-Abort Inhibit Command	135.1	$(134.2)_1$	IU	135.08	$(134.16)_1$	MSFC	- - -
25	Signal From LVDC for: Propellant Level Sensors Enable Command	135.3	$(134.4)_1$	IU	135.29	$(134.36)_1$	MSFC	- - -
26	S-IB Propellant Level Sensor Actuates (Start Time Base 2)	137.7	$(0.0)_2$	IU	136.52	$(0.00)_2$	MSFC	- - -
27	Stop Pitch Maneuver	137.9	N/A	IU	136.423	N/A	MSFC	- - -
28	Signal From LVDC for: IU Tape Recorder Record On Command	138.9	$(1.2)_2$	IU	137.69	$(1.17)_2$	MSFC	- - -

* Range Zero = 1715:32.0 (GMT)

TABLE 4-1 (Sheet 4 of 24)
FLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME (sec)		SIGNAL MONITORED AT	MONITORED TIME (sec)		DATA SOURCE	ACCURACY (ms)
		TIME FROM RANGE ZERO	TIME FROM BASE		TIME FROM RANGE ZERO*	TIME FROM BASE		
29a	Signal From LVDC for: Fast Record On Command	139.7	$(2.0)_2$	IU	138.478	$(1.95)_2$	MSFC	- - -
29b	Signal Received In S-IVB for: Fast Record On Command	- - -	- - -	S-IVB	138.479	- - -	DAC (FM)	13
30	Signal From LVDC for: Cameras Start Command	140.5	$(2.8)_2$	IU	139.28	$(2.76)_2$	MSFC	- - -
31	Signal From LVDC for: S-IB Inboard Engines Cutoff Command	140.8	$(3.1)_2$	IU	139.57	$(3.05)_2$	MSFC	- - -
32	Signal From LVDC for: Q-Ball Power Off Command	141.0	$(3.3)_2$	IU	139.77	$(3.25)_2$	MSFC	- - -
33a	Signal From LVDC for: Ullage Ignition Charge On Command	141.5	$(3.8)_2$	IU	140.277	$(3.75)_2$	MSFC	- - -
33b	Signal Received In S-IVB for: Ullage Ignition Charge On Command	- - -	- - -	S-IVB	140.276	- - -	DAC (FM)	13
33c	1. Ullage Rocket 1, EBW 1 Charge	- - -	- - -	S-IVB	140.5	- - -	DAC (PAM)	84
	2. Ullage Rocket 1, EBW 2 Charge	- - -	- - -	S-IVB	140.5	- - -	DAC (PAM)	84
	3. Ullage Rocket 2, EBW 1 Charge	- - -	- - -	S-IVB	140.5	- - -	DAC (PAM)	84
	4. Ullage Rocket 2, EBW 2 Charge	- - -	- - -	S-IVB	140.5	- - -	DAC (PAM)	84

* Range Zero = 1715:32.0 (GMT)

TABLE 4-1 (Sheet 5 of 24)
FLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME (sec)		SIGNAL MONITORED AT	MONITORED TIME (sec)		DATA SOURCE	ACCURACY (ms)
		TIME FROM RANGE ZERO	TIME FROM BASE		TIME FROM RANGE ZERO*	TIME FROM BASE		
33c (Cont)	5. Ullage Rocket 3, EBW 1 Charge	- - -	- - -	S-IVB	140.5	- - -	DAC (PAM)	84
	6. Ullage Rocket 3, EBW 2 Charge	- - -	- - -	S-IVB	140.5	- - -	DAC (PAM)	84
34a	Signal From LVDC for: Pre-Valves Open Command	142.1	$(4.4)_2$	IU	140.888	$(4.36)_2$	MSFC	- - -
34b	Signal Received In S-IVB for: Pre-Valves Open Command	- - -	- - -	S-IVB	140.880	- - -	DAC (FM)	13
34c	1. LOX Pre-Valve Open	- - -	- - -	S-IVB	143.0	- - -	DAC(PCM)	335
	2. LH2 Pre-Valve Open	- - -	- - -	S-IVB	143.0	- - -	DAC(PCM)	335
35	Signal From LVDC for: LOX Depletion Cutoff Enable Command	142.3	$(4.6)_2$	IU	141.08	$(4.56)_2$	MSFC	- - -
36	Signal From LVDC for: LH2 Depletion Cutoff Enable Command	143.3	$(5.6)_2$	IU	142.07	$(5.55)_2$	MSFC	- - -
37	S-IB Outboard Engines Cutoff (Start Time Base 3)	144.8	$(0.0)_3$	IU	143.47	$(0.00)_3$	MSFC	- - -
38a	Signal From LVDC for: S-IVB Engine Cutoff Command Off	145.2	$(0.4)_3$	IU	143.832	$(0.36)_3$	MSFC	- - -
38b	Signal Received in S-IVB for: S-IVB Engine Cutoff Command Off	- - -	- - -	S-IVB	143.835	- - -	DAC (FM)	13

* Range Zero = 1715:32.0 (GMT)

TABLE 4-1 (Sheet 6 of 24)
FLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME (sec)		SIGNAL MONITORED AT	MONITORED TIME (sec)		DATA SOURCE	ACCURACY (ms)
		TIME FROM RANGE ZERO	TIME FROM BASE		TIME FROM RANGE ZERO*	TIME FROM BASE		
39a	Signal From LVDC for: Ullage Rocket Ignition Fire Command On	145.4	$(0.6)_3$	IU	144.030	$(0.56)_3$	MSFC	- - -
39b	Signal Received in S-IVB for: Ullage Rocket Ignition Fire Command On	- - -	- - -	S-IVB	144.023	- - -	DAC (FM)	13
39c	1. Ullage Rocket 1, EBW 1 Fire	- - -	- - -	S-IVB	144.20	- - -	DAC(PAM)	84
	2. Ullage Rocket 1, EBW 2 Fire	- - -	- - -	S-IVB	144.20	- - -	DAC(PAM)	84
	3. Ullage Rocket 2, EBW 1 Fire	- - -	- - -	S-IVB	144.20	- - -	DAC(PAM)	84
	4. Ullage Rocket 2, EBW 2 Fire	- - -	- - -	S-IVB	144.20	- - -	DAC(PAM)	84
	5. Ullage Rocket 3, EBW 1 Fire	- - -	- - -	S-IVB	144.20	- - -	DAC(PAM)	84
	6. Ullage Rocket 3, EBW 2 Fire	- - -	- - -	S-IVB	144.20	- - -	DAC(PAM)	84
40	Signal From LVDC for: S-IB/S-IVB Separation Device and Retrorockets Fire Command	145.6	$(0.8)_3$	IU	144.27	$(0.80)_3$	MSFC	- - -
41	Ullage Thrust Buildup to 75% (Avg)	- - -	- - -		144.28	- - -	DAC **	- - -
42	S-IB Retrorocket Thrust Buildup to 10% (Avg)	- - -	- - -		144.32	- - -	DAC **	- - -

* Range Zero = 1715:32.0 (GMT)
** Analytical

TABLE 4-1 (Sheet 7 of 24)
FLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME (sec)		SIGNAL MONITORED AT	MONITORED TIME (sec)		DATA SOURCE	ACCURACY (ms)
		TIME FROM RANGE ZERO	TIME FROM BASE		TIME FROM RANGE ZERO*	TIME FROM BASE		
43	First Axial Separation Motion	- - -	- - -		144.33	N/A	DAC **	- - -
44	S-IB Retrorocket Thrust Buildup to 90% (Avg)	- - -	- - -		144.34	N/A	DAC **	- - -
45	Signal From LVDC Flight Control To Computer for: S-IVB Burn Mode On Command	145.8	$(1.0)_3$	IU	144.43	$(0.96)_3$	MSFC	- - -
46a	Signal From LVDC for: Engine Ready Bypass Command	146.0	$(1.2)_3$	IU	144.630	$(1.16)_3$	MSFC	- - -
46b	Signal Received In S-IVB for: Engine Ready Bypass Command	- - -	- - -	S-IVB	144.627	- - -	DAC (FM)	13
47a	Signal From LVDC for: Engine Start Interlock Bypass On Command	146.2	$(1.4)_3$	IU	144.830	$(1.36)_3$	MSFC	- - -
47b	Signal Received in S-IVB for: Engine Start Interlock Bypass On Command	- - -	- - -	S-IVB	144.840	- - -	DAC (FM)	13
48a	Signal From LVDC for: LH2 Chilldown Pump Off Command	146.4	$(1.6)_3$	IU	145.030	$(1.56)_3$	MSFC	- - -
48b	Signal Received in S-IVB for: LH2 Chilldown Pump Off Command	- - -	- - -	S-IVB	145.019	- - -	DAC (FM)	13

* Range Zero = 1715:32.0 (GMT)
** Analytical

TABLE 4-1 (Sheet 8 of 24)
FLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME (sec)		SIGNAL MONITORED AT	MONITORED TIME (sec)		DATA SOURCE	ACCURACY (ms)
		TIME FROM RANGE ZERO	TIME FROM BASE		TIME FROM RANGE ZERO*	TIME FROM BASE		
49a	Signal From LVDC for: LOX Chilldown Pump Off Command	146.6	$(1.8)_3$	IU	145.230	$(1.76)_3$	MSFC	- - -
49b	Signal Received In S-IVB for: LOX Chilldown Pump Off Command	- - -	- - -	S-IVB	145.223	- - -	DAC (FM)	13
50a	Signal From LVDC for: Chilldown Pumps Discharge Valves Off Command	146.8	$(2.0)_3$	IU	145.430	$(1.96)_3$	MSFC	13
50b	Signal Received In S-IVB for: Chilldown Pumps Discharge Valves Off Command	- - -	- - -	S-IVB	145.422	- - -	DAC (FM)	13
50c	1. LOX Chilldown System Closed	- - -	- - -	S-IVB	145.642	- - -	DAC(PAM)	84
	2. LH2 Chilldown System Closed	- - -	- - -	S-IVB	146.2	- - -	DAC(PAM)	84
51a	Signal From LVDC for: S-IVB Engine Start Command On	147.0	$(2.2)_3$	IU	145.630	$(2.16)_3$	MSFC	- - -
51b	Signal Received In S-IVB for: S-IVB Engine Start Command On	- - -	- - -	S-IVB	145.624	- - -	DAC (FM)	13
51c	1. Helium Control Solenoid Energized	- - -	- - -	S-IVB	145.660	- - -	DAC (FM)	13
	2. Main Fuel Valve Closed (Drop Out)	- - -	- - -	S-IVB	146.801	- - -	DAC(PCM)	9

* Range Zero = 1715:32.0 (GMT)

TABLE 4-1 (Sheet 9 of 24)
FLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME (sec)		SIGNAL MONITORED AT	MONITORED TIME (sec)		DATA SOURCE	ACCURACY (ms)
		TIME FROM RANGE ZERO	TIME FROM BASE		TIME FROM RANGE ZERO*	TIME FROM BASE		
51c (Cont)	3. Main Fuel Valve Open (Pick Up)	- - -	- - -	S-IVB	146.800	- - -	DAC(PCM)	9
	4. Gas Generator Valve Closed (Drop Out)	- - -	- - -	S-IVB	147.159	- - -	DAC(PCM)	9
	5. Gas Generator Valve Open (Pick Up)	- - -	- - -	S-IVB	147.301	- - -	DAC(PCM)	35
	6. Main Oxidizer Valve Leaves Closed Position (Drop Out)	- - -	- - -	S-IVB	147.351	- - -	DAC(PCM)	9
	7. Start Tank Discharge Valve Open (Drop Out)	- - -	- - -	S-IVB	147.359	- - -	DAC(PCM)	9
	8. Oxidizer Turbine Bypass Valve Open (Drop Out)	- - -	- - -	S-IVB	147.367	- - -	DAC(PCM)	9
	9. Oxidizer Turbine Bypass Valve Closed (Pick Up)	- - -	- - -	S-IVB	147.559	- - -	DAC(PCM)	9
	10. Mainstage OK Pressure Switch 1 (Drop Out)	- - -	- - -	S-IVB	148.467	- - -	DAC(PCM)	84
	11. Mainstage OK Pressure Switch 2 (Pick Up)	- - -	- - -	S-IVB	148.467	- - -	DAC(PCM)	84
	12. Main Oxidizer Valve Reaches Open Position (Pick Up)	- - -	- - -	S-IVB	149.901	- - -	DAC(PCM)	9

* Range Zero = 1715:32.0 (GMT)

TABLE 4-1 (Sheet 10 of 24)
FLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME (sec)		SIGNAL MONITORED AT	MONITORED TIME (sec)		DATA SOURCE	ACCURACY (ms)
		TIME FROM RANGE ZERO	TIME FROM BASE		TIME FROM RANGE ZERO*	TIME FROM BASE		
51c (Cont)	13. Gas Generator Spark System On (Drop Out)	- - -	- - -	S-IVB	150.377	- - -	DAC(PCM)	9
	14. Thrust Chamber Spark System On (Drop Out)	- - -	- - -	S-IVB	150.377	- - -	DAC(PCM)	9
52	Signal From LVDC for: EDS Arming of S-IVB Engine Pressure Switches Command	147.2	$(2.4)_3$	IU	145.83	$(2.36)_3$	MSFC	- - -
53a	Signal From LVDC for: Engine Start Command Off	147.5	$(2.7)_3$	IU	146.130	$(2.66)_3$	MSFC	- - -
53b	Signal Received In S-IVB for: Engine Start Command Off	- - -	- - -	S-IVB	146.124	- - -	DAC (FM)	13
54a	Signal From LVDC for: LOX Flight Pressurization System On Command	147.8	$(3.0)_3$	IU	146.430	$(2.96)_3$	MSFC	- - -
54b	Signal Received In S-IVB for: LOX Flight Pressurization System On Command	- - -	- - -	S-IVB	146.423	- - -	DAC (FM)	13
55a	Signal From LVDC for: Fuel Injection Temperature Bypass On Command	148.0	$(3.2)_3$	IU	146.630	$(3.16)_3$	MSFC	- - -
55b	Signal Received In S-IVB for: Fuel Injection Temperature Bypass On Command	- - -	- - -	S-IVB	146.622	- - -	DAC (FM)	13

* Range Zero = 1715:32.0 (GMT)

TABLE 4-1 (Sheet 11 of 24)
FLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME (sec)		SIGNAL MONITORED AT	MONITORED TIME (sec)		DATA SOURCE	ACCURACY (ms)
		TIME FROM RANGE ZERO	TIME FROM BASE		TIME FROM RANGE ZERO*	TIME FROM BASE		
56	J-2 Engine At 10 Percent Thrust	149.0	N/A	- - -	147.616	N/A	DAC **	- - -
57	Ullage Rocket Motors Burnout (Average)	149.4	N/A	- - -	148.03	N/A	DAC **	- - -
58a	Engine Burning #1 Relay On	149.8	$(5.0)_3$	IU	148.422	$(4.95)_3$	MSFC	- - -
58b	Signal Received in S-IVB for: Engine Burning #1 Relay On	- - -	- - -	S-IVB	148.425	- - -	DAC (FM)	13
59	J-2 Engine At 90 Percent Thrust (Defined As P_c = 618 psi)	150.4	N/A	- - -	149.126	N/A	DAC **	- - -
60a	Signal From LVDC for: Engine Start Inter-lock Bypass Off Command	152.8	$(8.0)_3$	IU	151.421	$(7.95)_3$	MSFC	- - -
60b	Signal Received In S-IVB for: Engine Start Inter-Lock Bypass Off Command	- - -	- - -	S-IVB	151.427	- - -	DAC (FM)	13
61a	Signal From LVDC for: PU Activate On Command	153.0	$(8.2)_3$	IU	151.628	$(8.16)_3$	MSFC	- - -
61b	Signal Received in S-IVB for: PU Activate On Command	- - -	- - -	S-IVB	151.628	- - -	DAC (FM)	13
62a	Signal From LVDC for: Emergency Playback Enable On Command	153.2	$(8.4)_3$	IU	150.829	$(8.36)_3$	MSFC	- - -

* Range Zero = 1715:32.0 (GMT)
** Analytical

TABLE 4-1 (Sheet 12 of 24)
FLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME (sec)		SIGNAL MONITORED AT	MONITORED TIME (sec)		DATA SOURCE	ACCURACY (ms)
		TIME FROM RANGE ZERO	TIME FROM BASE		TIME FROM RANGE ZERO*	TIME FROM BASE		
62b	Signal Received in S-IVB for: Emergency Playback Enable On Command	- - -	- - -	S-IVB	151.830	- - -	DAC (FM)	13
63a	Signal From LVDC for: Fast Record Off Command	153.4	$(8.6)_3$	IU	152.031	$(8.56)_3$	MSFC	- - -
63b	Signal Received in S-IVB for: Fast Record Off Command	- - -	- - -	S-IVB	152.031	- - -	DAC (FM)	13
64a	Signal From LVDC for: Ullage-Rocket Jettison Units Charge On Command	154.5	$(9.7)_3$	IU	153.147	$(9.68)_3$	MSFC	- - -
64b	Signal Received in S-IVB for: Ullage Rocket Jettison Units Charge On Command	- - -	- - -	S-IVB	153.149	- - -	DAC (FM)	13
	1. Jettison Unit 1, Charge	- - -	- - -	S-IVB	153.3	- - -	DAC(PAM)	84
	2. Jettison Unit 2, Charge	- - -	- - -	S-IVB	153.3	- - -	DAC(PAM)	84
65a	Signal From LVDC for: Ullage - Rocket Jettison Units Fire On Command	157.6	$(12.8)_3$	IU	156.221	$(12.75)_3$	MSFC	- - -
65b	Signal Received In S-IVB for: Ullage Rockets Jettison Units Fire On Command	- - -	- - -	S-IVB	156.222	- - -	DAC (FM)	13

* Range Zero = 1715:32.0 (GMT)

TABLE 4-1 (Sheet 13 of 24)
FLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME (sec)		SIGNAL MONITORED AT	MONITORED TIME (sec)		DATA SOURCE	ACCURACY (ms)
		TIME FROM RANGE ZERO	TIME FROM BASE		TIME FROM RANGE ZERO*	TIME FROM BASE		
65b (Cont)	1. Jettison Unit 1, Fire	- - -	- - -	S-IVB	156.22	- - -	DAC(PAM)	84
	2. Jettison Unit 2, Fire	- - -	- - -	S-IVB	156.22	- - -	DAC(PAM)	84
66	Signal From LVDC for: Water Coolant Valve Open Command	161.1	$(16.3)_3$	IU	159.72	$(16.20)_3$	MSFC	- - -
67a	Signal From LVDC for: Ullage - Rocket Jettison Units Charge Off Command	163.6	$(18.8)_3$	IU	162.221	$(18.75)_3$	MSFC	- - -
67b	Signal Received in S-IVB for: Ullage-Rocket Jettison Units Charge Off Command	- - -	- - -	S-IVB	162.220	- - -	DAC (FM)	13
68a	Signal From LVDC for: Ullage Rocket Jettison Units Fire Off Command	163.8	$(19.0)_3$	IU	162.432	$(18.96)_3$	MSFC	- - -
68b	Signal Received In S-IVB for: Ullage Rocket Jettison Units Fire Off Command	- - -	- - -	S-IVB	162.431	- - -	DAC (FM)	- - -
69	Signal From LVDC for: IU Tape Recorder Record Off Command	166.2	$(21.4)_3$	IU	164.84	$(21.37)_3$	MSFC	- - -
70a	Signal From LVDC for: Emergency Playback Enable Off Command	167.2	$(22.4)_3$	IU	165.825	$(22.36)_3$	MSFC	- - -

* Range Zero = 1715:32.0 (GMT)

TABLE 4-1 (Sheet 14 of 24)
FLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME (sec)		SIGNAL MONITORED AT	MONITORED TIME (sec)		DATA SOURCE	ACCURACY (ms)
		TIME FROM RANGE ZERO	TIME FROM BASE		TIME FROM RANGE ZERO*	TIME FROM BASE		
70b	Signal Received in S-IVB for: Emergency Playback Enable Off Command	- - -	- - -	S-IVB	165.825	- - -	DAC (FM)	13
71	Signal From LVDC for:							
	1. Launch Escape System A Jettison On Command	170.3	$(25.5)_3$	IU	168.93	$(25.46)_3$	MSFC	- - -
	2. Launch Escape System B Jettison On Command	170.5	$(25.7)_3$	IU	169.13	$(25.66)_3$	MSFC	- - -
72	Signal From LVDC for: Telemetry Calibrator Inflight Calibration Command	170.9	$(26.1)_3$	IU	169.54	$(26.07)_3$	MSFC	- - -
73	Iterative Guidance Start	173.7	N/A	IU	172.4	N/A	MSFC	- - -
74	Signal From LVDC for: Telemetry Calibrator Stop Inflight Calibration Command	175.9	$(31.1)_3$	IU	174.52	$(31.05)_3$	MSFC	- - -
75	Signal From LVDC for: Telemetry Calibrator Inflight Calibration Command	350.9	$(206.1)_3$	IU	349.52	$(206.05)_3$	MSFC	- - -
76a	Signal From LVDC for: Regular Calibration Relays On Command	352.6	$(207.8)_3$	IU	351.222	$(207.75)_3$	MSFC	- - -

* Range Zero = 1715:32.0 (GMT)

TABLE 4-1 (Sheet 15 of 24)
FLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME (sec)		SIGNAL MONITORED AT	MONITORED TIME (sec)		DATA SOURCE	ACCURACY (ms)
		TIME FROM RANGE ZERO	TIME FROM BASE		TIME FROM RANGE ZERO*	TIME FROM BASE		
76b	Signal Received in S-IVB for: Regular Calibration Relays On Command	- - -	- - -	S-IVB	351.223	- - -	DAC (FM)	13
77	Signal From LVDC for: Telemetry Calibrator Stop Inflight Calibration Command	355.9	$(211.1)_3$	IU	354.522	$(211.05)_3$	MSFC	- - -
78a	Signal From LVDC for: Regular Calibration Relays Off Command	357.1	$(212.3)_3$	IU	355.722	$(212.25)_3$	MSFC	- - -
78b	Signal Received in S-IVB for: Regular Calibration Relays Off Command	- - -	- - -	S-IVB	355.723	- - -	DAC (FM)	- - -
79	Signal From LVDC to Flight Control Computer for: Switch Point #3	406.8	$(252.0)_3$	IU	395.463	$(251.99)_3$	MSFC	- - -
80a	Signal From LVDC for: Engine Burning #1 Relay Off Command	447.2	$(302.4)_3$	IU	445.832	$(302.36)_3$	MSFC	- - -
80b	Signal Received In S-IVB for: Engine Burning #1 Relay Off Command	- - -	- - -	S-IVB	445.831	- - -	DAC (FM)	- - -
81	S-IVB Engine Mixture Ratio Cutback	451.6	N/A		475.7	N/A	DAC**	

* Range Zero = 1715:32.0 (GMT)
** Analytical

TABLE 4-1 (Sheet 16 of 24)
FLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME (sec)		SIGNAL MONITORED AT	MONITORED TIME (sec)		DATA SOURCE	ACCURACY (ms)
		TIME FROM RANGE ZERO	TIME FROM BASE		TIME FROM RANGE ZERO*	TIME FROM BASE		
82	Introduction of Guidance Staging and Artificial τ Guidance Mode	471.0	N/A	IU	499.1	N/A	MSFC	- - -
83	End of Artificial τ Guidance Mode	501.0	N/A	IU	529.8	N/A	MSFC	- - -
84	Signal From LVDC for: Telemetry Calibrator In-Flight Calibration Command	500.9	$(356.1)_3$	IU	499.53	$(356.08)_3$	MSFC	- - -
85	Signal From LVDC for: Telemetry Calibrator Stop In-Flight Calibration Command	505.9	$(361.1)_3$	IU	504.52	$(361.05)_3$	MSFC	- - -
86	Introduction of $\tilde{\chi}$ Guidance Mode	555.7	N/A	IU	546.0	N/A	MSFC	- - -
87a	Signal From LVDC for: Arm the Depletion Sensors Command	583.1	$(438.3)_3$	IU	581.740	$(438.27)_3$	MSFC	- - -
87b	Signal Received In S-IVB for: Arm The Depletion Sensors Command	- - -	- - -	S-IVB	581.743	- - -	DAC (FM)	13.2
88	End $\tilde{\chi}$ Guidance Mode (Start χ Freeze)	599.5	N/A	IU	587.01	N/A	MSFC	- - -
89a	Signal From LVDC for: S-IVB Engine Cutoff Command On	601.5	N/A	IU	588.471	N/A	MSFC	- - -

* Range Zero = 1715:32.0 (GMT)

TABLE 4-1 (Sheet 17 of 24)
FLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME (sec)		SIGNAL MONITORED AT	MONITORED TIME (sec)		DATA SOURCE	ACCURACY (ms)
		TIME FROM RANGE ZERO	TIME FROM BASE		TIME FROM RANGE ZERO*	TIME FROM BASE		
89b	Signal Received In S-IVB for: S-IVB Engine Cutoff Command On	- - -	- - -	S-IVB	588.473	- - -	DAC (FM)	13
	1. Ignition Phase Control Solenoid Energized (Drop Out)	- - -	- - -	S-IVB	588.6	- - -	DAC(PAM)	9
	2. Engine Cutoff Command (Pick up)	- - -	- - -	S-IVB	588.476	- - -	DAC (FM)	5
	3. Main Oxidizer Valve Closed	- - -	- - -	S-IVB	588.7	- - -	DAC(PAM)	9
	4. J-2 Engine Thrust Level Drops to 90%	- - -	- - -	S-IVB	588.634	- - -	DAC (FM)	- - -
	5. Start Time Base #4	N/A	$(0.0)_4$	IU	588.71	$(0.00)_4$	MSFC	- - -
	6. J-2 Engine Thrust Level Drops to 10%	- - -	- - -	S-IVB	588.876	- - -	DAC (FM)	- - -
	7. Helium Control Solenoid Energized (Drop Off)	- - -	- - -	S-IVB	589.442	- - -	DAC (FM)	5
90a	Signal From LVDC for: LOX Ullage Thrust Control Valve Open Command	602.1	$(0.4)_4$	IU	589.084	$(0.37)_4$	MSFC	- - -
90b	Signal Received In S-IVB for: LOX Ullage Thrust Control Valve Open Command	- - -	- - -	S-IVB	589.089	- - -	DAC (FM)	13

* Range Zero = 1715:32.0 (GMT)

TABLE 4-1 (Sheet 18 of 24)
FLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME (sec)		SIGNAL MONITORED AT	MONITORED TIME (sec)		DATA SOURCE	ACCURACY (ms)
		TIME FROM RANGE ZERO	TIME FROM BASE		TIME FROM RANGE ZERO*	TIME FROM BASE		
91a	Signal From LVDC for: Prevalves Close Command	602.3	$(0.6)_4$	IU	589.269	$(0.55)_4$	LVDC	- - -
91b	Signal Received In S-IVB for: Prevalves Close Command	- - -	- - -	S-IVB	589.273	- - -	DAC (FM)	13
92a	Signal From LVDC for: Coast Period On Command	602.5	$(0.8)_4$	IU	589.474	$(0.76)_4$	MSFC	- - -
92b	Signal Received In S-IVB for: Coast Period On Command	- - -	- - -	S-IVB	589.479	- - -	DAC (FM)	13
93a	Signal From LVDC for: LOX Tank Flight Pressure System Off Command	602.9	$(1.2)_4$	IU	589.871	$(1.15)_4$	MSFC	- - -
93b	Signal Received In S-IVB for: LOX Tank Flight Pressure System Off Command	- - -	- - -	S-IVB	589.875	- - -	DAC (FM)	13
94a	Signal From LVDC for: S-IVB Engine Cutoff Command Off	603.1	$(1.4)_4$	IU	590.070	$(1.35)_4$	MSFC	- - -
94b	Signal Received In S-IVB for: S-IVB Engine Cutoff Command Off	- - -	- - -	S-IVB	590.075	- - -	DAC (FM)	13
95a	Signal From LVDC for: LOX Chilldown Pump Purge Control Valve Open Off Command	603.3	$(1.6)_4$	IU	590.269	$(1.55)_4$	MSFC	- - -

* Range Zero = 1715:32.0 (GMT)

TABLE 4-1 (Sheet 19 of 24)
FLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME (sec)		SIGNAL MONITORED AT	MONITORED TIME (sec)		DATA SOURCE	ACCURACY (ms)
		TIME FROM RANGE ZERO	TIME FROM BASE		TIME FROM RANGE ZERO*	TIME FROM BASE		
95b	Signal Received In S-IVB for: LOX Chilldown Pump Purge Control Valve Open Command	- - -	- - -	S-IVB	590.275	- - -	DAC (FM)	13
96a	Signal From LVDC for: Disarm the Depletion Sensors Command	603.5	$(1.8)_4$	IU	590.474	$(1.76)_4$	MSFC	- - -
96b	Signal Received In S-IVB for: Disarm the Depletion Sensors Command	- - -	- - -	S-IVB	590.479	- - -	DAC (FM)	13
97a	Signal From LVDC for: Range System Safety Off Enable Command	603.7	$(2.0)_4$	IU	590.690	$(1.97)_4$	MSFC	- - -
97b	Signal Received In S-IVB for: Range System Safety Off Enable Command	- - -	- - -	S-IVB	590.697	- - -	DAC (FM)	13
98a	Signal From LVDC for: PU Activate Off Command	603.9	$(2.2)_4$	IU	590.871	$(2.15)_4$	MSFC	- - -
98b	Signal Received In S-IVB for: PU Activate Off Command	- - -	- - -	S-IVB	590.875	- - -	DAC (FM)	13
99a	Signal From LVDC for: PU Inverter and DC Power Off Command	604.3	$(2.6)_4$	IU	591.276	$(2.56)_4$	MSFC	- - -
99b	Signal Received In S-IVB for: PU Inverter and DC Power Off Command	- - -	- - -	S-IVB	591.280	- - -	DAC (FM)	13

* Range Zero = 1715:32.0 (GMT)

TABLE 4-1 (Sheet 20 of 24)
FLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME (sec)		SIGNAL MONITORED AT	MONITORED TIME (sec)		DATA SOURCE	ACCURACY (ms)
		TIME FROM RANGE ZERO	TIME FROM BASE		TIME FROM RANGE ZERO*	TIME FROM BASE		
100	Signal From LVDC for: Flight Control Computer S-IVB Burn Mode Off Command	606.7	$(5.0)_4$	IU	593.68	$(4.96)_4$	MSFC	- - -
101a	Signal From LVDC for: PU Inverter and DC Power Off Command	606.9	$(5.2)_4$	IU	593.886	$(5.17)_4$	MSFC	
101b	Signal Received In S-IVB for: Auxiliary Hydraulic Pump Off Command	- - -	- - -	S-IVB	593.891	- - -	DAC (FM)	13
102a	Signal From LVDC for: LOX Tank Vent Open Off Command	609.6	$(7.9)_4$	IU	596.586	$(7.87)_4$	MSFC	- - -
102b	Signal Received In S-IVB for: LOX Tank Vent Open Off Command	- - -	- - -	S-IVB	596.594	- - -	DAC (FM)	13
103a	Signal From LVDC For: LOX Tank Vent Boost Closed On Command	609.8	$(8.1)_4$	IU	596.790	$(8.07)_4$	MSFC	- - -
103b	Signal Received In S-IVB for: LOX Tank Vent Boost Closed On Command	- - -	- - -	S-IVB	596.798	- - -	DAC (FM)	13
104a	Signal From LVDC for: LV/SC Separation Sequence Start Command	610.1	$(8.3)_4$	IU	596.97	$(8.25)_4$	MSFC	- - -
104b	Physical LV/SC Separation	611.5	N/A	--	599	N/A	DAC**	- - -
104c	SPS First Ignition	621.5	N/A	--	610	N/A	DAC**	- - -

* Range Zero = 1715:32.0 (GMT)
** Analytical

TABLE 4-1 (Sheet 21 of 24)
FLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME (sec)		SIGNAL MONITORED AT	MONITORED TIME (sec)		DATA SOURCE	ACCURACY (ms)
		TIME FROM RANGE ZERO	TIME FROM BASE		TIME FROM RANGE ZERO*	TIME FROM BASE		
105a	Signal From LVDC for: LOX Tank Vent Boost Closed Off Command	611.8	$(10.1)_4$	IU	598.772	$(10.05)_4$	MSFC	- - -
105b	Signal Received In S-IVB for: LOX Tank Vent Boost Closed Off Command	- - -	- - -	S-IVB	598.778	- - -	DAC (FM)	13
106a	Signal From LVDC for: Special Calibrate Relays On Command	624.7	$(23.0)_4$	IU	611.681	$(22.96)_4$	MSFC	- - -
106b	Signal Received In S-IVB for: Special Calibrate Relays On Command	- - -	- - -	S-IVB	611.689	- - -	DAC (FM)	13
107a	Signal From LVDC for: Regular Calibrate Relays On Command	624.9	$(23.2)_4$	IU	611.886	$(23.17)_4$	MSFC	- - -
107b	Signal Received In S-IVB for: Regular Calibrate Relays On Command	- - -	- - -	S-IVB	611.895	- - -	DAC (FM)	13
108a	Signal From LVDC for: Regular Calibrate Relays Off Command	629.7	$(28.0)_4$	IU	616.670	$(27.95)_4$	MSFC	- - -
108b	Signal Received In S-IVB for: Regular Calibrate Relays Off Command	- - -	- - -	S-IVB	616.676	- - -	DAC (FM)	13

* Range Zero = 1715:32.0 (GMT)

TABLE 4-1 (Sheet 22 of 24)
FLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME (sec)		SIGNAL MONITORED AT	MONITORED TIME (sec)		DATA SOURCE	ACCURACY (ms)
		TIME FROM RANGE ZERO	TIME FROM BASE		TIME FROM RANGE ZERO*	TIME FROM BASE		
109a	Signal From LVDC for: Special Calibrate Relays Off Command	629.9	$(28.2)_4$	IU	616.871	$(28.15)_4$	MSFC	- - -
109b	Signal Received In S-IVB for: Special Calibrate Relays Off Command	- - -	- - -	S-IVB	616.878	- - -	DAC (FM)	13
110	Signal From LVDC for: IU Tape Recorder Playback Reverse On Command	639.8	$(38.1)_4$	IU	626.770	$(38.05)_4$	MSFC	- - -
111a	Signal From LVDC for: Tape Recorder Playback On Command	640.0	$(38.3)_4$	IU	626.971	$(38.25)_4$	MSFC	- - -
111b	Signal Received In S-IVB for: Tape Recorder Playback On Command	- - -	- - -	S-IVB	626.981	- - -	DAC (FM)	13
112a	Signal From LVDC for: Chilldown Shutoff Pilot Valve Close Off Command	661.7	$(60.0)_4$	IU	648.674	$(59.95)_4$	MSFC	- - -
112b	Signal Received In S-IVB for: Chilldown Shutoff Pilot Valve Close Off Command	- - -	- - -	S-IVB	Not** Available	- - -	DAC (FM)	- - -
113a	Signal From LVDC for: Prevalves Close Off Command	661.9	$(60.2)_4$	IU	648.878	$(60.16)_4$	MSFC	- - -

* Range Zero = 1715:32.0 (GMT)

** Data was not recorded due to tape recorder playback operation.

TABLE 4-1 (Sheet 23 of 24)
FLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME (sec)		SIGNAL MONITORED AT	MONITORED TIME (sec)		DATA SOURCE	ACCURACY (ms)
		TIME FROM RANGE ZERO	TIME FROM BASE		TIME FROM RANGE ZERO*	TIME FROM BASE		
113b	Signal Received In S-IVB for: Prevalves Close Off Command	- - -	- - -	S-IVB	Not** Available	- - -	DAC (FM)	- - -
114	Signal From LVDC for: IU Tape Recorder Playback. Reverse Off Command	699.8	$(68.1)_4$	IU	656.778	$(68.06)_4$	MSFC	- - -
115a	Signal From LVDC for: Tape Recorder Playback Off Command	670.0	$(68.3)_4$	IU	656.979	$(68.26)_4$	MSFC	- - -
115b	Signal Received In S-IVB for: Tape Recorder Playback Off Command	- - -	- - -	S-IVB	656.973	- - -	DAC (FM)	13
116a	Signal From LVDC for: LOX Tank Vent Open On Command	691.7	$(90.0)_4$	IU	678.678	$(89.96)_4$	MSFC	- - -
116b	Signal Received In S-IVB for: LOX Tank Vent Open On Command	699.8	$(98.1)_4$	IU	686.778	$(98.06)_4$	DAC (FM)	13
117	Signal From LVDC for: Telemetry Calibrator In-Flight Calibrate Command	699.8	$(98.1)_4$	IU	686.778	$(98.06)_4$	MSFC	- - -
118	Start Pitch, Yaw, and Roll Maneuver	700.8	N/A	- - -	689.5	N/A	DAC (FM)	- - -

* Range Zero = 1715:32.0 (GMT)
** Data was not recorded due to tape recorder playback operation

TABLE 4-1 (Sheet 24 of 24)
FLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME (sec)		SIGNAL MONITORED AT	MONITORED TIME (sec)		DATA SOURCE	ACCURACY (ms)
		TIME FROM RANGE ZERO	TIME FROM BASE		TIME FROM RANGE ZERO*	TIME FROM BASE		
119	Signal From LVDC for: Telemetry Calibrator Stop In-Flight Calibrate Command	704.8	$(103.1)_4$	IU	691.775	$(103.06)_4$	MSFC	- - -
120	Loss of S-IVB Telemetry Signal	- - -	- - - - -	- -	941	- - -	DAC**	

* Range Zero = 1715:32.0 (GMT)
** Analytical

TABLE 4-2 (Sheet 1 of 2)
GROUND SEQUENCE OF EVENTS

TIME MIN	TIME SEC	INDICATION	EVENT
-14	35.333	Off	Inflight Relays On
	35.327	Off	Telemetry Ready
	30.420	Off	Start Tank Purge Valve Open
	30.411	On	Start Tank Purge Valve Closed
	29.844	Off	Start Tank Supply Valve Closed
	29.839	On	Start Tank Supply Valve Open
	29.836	On	Start Bottle Pressurizing
	14.642	On	Maximum Level Sensors Wet
	14.642	On	Hi Level Sensors Wet
-13	40.840	Off	Switch Selector Zero
	40.840	On	S-IVB Switch Selector Enable
	40.744	On	Switch Selector Read
	40.744	Off	Special Cal Relays Off
	40.687	Off	S-IVB Switch Selector Enable
	40.687	Off	Switch Selector Read
	40.681	On	Switch Selector Zero
	40.616	Off	Switch Selector Zero
	40.616	On	S-IVB Switch Selector Enable
	40.567	On	Switch Selector Read
	40.567	Off	Reg Calibration Relays Off
	40.504	Off	S-IVB Switch Selector Enable
	40.504	Off	Switch Selector Read
	40.498	On	Switch Selector Zero
	39.372	Off	Switch Selector Zero
	39.372	On	S-IVB Switch Selector Enable
	39.322	On	Switch Selector Read
	39.141	Off	S-IVB Switch Selector Enable
	39.141	Off	Switch Selector Read
	39.135	On	Switch Selector Zero
-12	27.192	On	Inflight Relays On
	27.189	On	Telemetry Ready
	26.148	Off	Inflight Relays On
	26.143	Off	Telemetry Ready
	26.102	Off	Switch Selector Zero
	26.102	On	S-IVB Switch Selector Enable
	26.052	On	Switch Selector Read
	26.044	On	Inflight Relays On
	26.041	On	Telemetry Ready
	25.988	Off	S-IVB Switch Selector Enable
	25.988	Off	Switch Selector Read
	25.982	On	Switch Selector Zero
	24.640	Off	Switch Selector Zero
	24.640	On	S-IVB Switch Selector Enable
	24.590	On	Switch Selector Read
	24.590	On	Reg Calibration Relays On
	24.533	Off	S-IVB Switch Selector Enable
	24.532	Off	Switch Selector Read
	24.526	On	Switch Selector Zero
	18.908	Off	Switch Selector Zero
	18.908	On	S-IVB Switch Selector Enable
	18.858	On	Switch Selector Read
	18.858	Off	Reg Calibration Relays Off
	18.801	Off	S-IVB Switch Selector Enable
	18.800	Off	Switch Selector Read
	18.795	On	Switch Selector Zero
	18.654	Off	Switch Selector Zero
	18.654	On	S-IVB Switch Selector Enable
	18.605	On	Switch Selector Read
	18.605	On	Special Calibration Relays On

TIME MIN	TIME SEC	INDICATION	EVENT
-12	18.547	Off	S-IVB Switch Selector Enable
	18.547	Off	Switch Selector Read
	18.541	On	Switch Selector Zero
	18.371	Off	Switch Selector Zero
	18.371	On	S-IVB Switch Selector Enable
	18.321	On	Switch Selector Read
	18.321	On	Reg Calibration Relays On
	18.264	Off	S-IVB Switch Selector Enable
	18.264	Off	Switch Selector Read
	18.258	On	Switch Selector Zero
	17.021	Off	Cold Heat Exchanger CKT 1 VV Closed
	17.020	On	Cold Heat Exchanger CKT 1 VV Open
	13.153	Off	Switch Selector Zero
	13.153	On	S-IVB Switch Selector Enable
	13.103	On	Switch Selector Read
	13.103	Off	Special Calibration Relays Off
	13.041	Off	S-IVB Switch Selector Enable
	13.040	Off	Switch Selector Read
	13.034	On	Switch Selector Zero
	12.970	Off	Switch Selector Zero
	12.970	On	S-IVB Switch Selector Enable
	12.920	On	Switch Selector Read
	12.920	Off	Reg Calibration Relays Off
	12.863	Off	S-IVB Switch Selector Enable
	12.862	Off	Switch Selector Read
	12.857	On	Switch Selector Zero
	12.766	Off	Switch Selector Zero
	12.766	On	S-IVB Switch Selector Enable
	12.699	On	Switch Selector Read
	12.642	Off	S-IVB Switch Selector Enable
	12.642	Off	Switch Selector Read
	12.638	On	Switch Selector Zero
-11	53.718	Off	Switch Selector Zero
	53.718	On	S-IVB Switch Selector Enable
	53.669	On	Switch Selector Read
	53.569	Off	S-IVB Switch Selector Enable
	53.569	Off	Switch Selector Read
	53.563	On	Switch Selector Zero
	00.410	Off	Switch Selector Zero
-10	00.410	On	S-IVB Switch Selector Enable
	00.361	Off	LOX Chilldown Relay Reset
	00.361	On	Switch Selector Read
	00.305	Off	S-IVB Switch Selector Enable
	00.304	Off	Switch Selector Read
	00.298	On	Switch Selector Zero
-9	56.764	Off	Switch Selector Zero
	56.764	On	S-IVB Switch Selector Enable
	56.715	Off	LH2 Chilldown Relay Reset
	56.715	On	Switch Selector Read
	56.658	Off	S-IVB Switch Selector Enable
	56.658	Off	Switch Selector Read
	56.652	On	Switch Selector Zero
	51.078	Off	Switch Selector Zero
	51.078	On	S-IVB Switch Selector Enable
	51.029	On	Switch Selector Read
	51.029	On	Prevalves Closed On
	50.972	Off	S-IVB Switch Selector Enable
	50.972	Off	Switch Selector Read
	50.966	On	Switch Selector Zero
	50.877	Off	LH2 Prevalve Open

TIME MIN	TIME SEC	INDICATION	EVENT
-9	50.869	Off	LOX Prevalve Open
	50.566	On	LH2 Prevalve Closed
	50.385	On	LOX Prevalve Closed
	50.379	On	Recirculation Oxidizer
-8	18.142	Off	Maximum Level Sensors Wet
	18.142	Off	Hi Level Sensors Wet
	18.142	Off	Low Level Sensors Wet
-7	02.318	On	Launch Sequence Ready Indication
-6	41.154	Off	Checkout Measurement Group On
	07.820	On	S-IVB Switch Selector enable
	07.603	Off	S-IVB Switch Selector Enable
	06.924	Off	Switch Selector Zero
	01.919	On	Switch Selector Read
	01.919	On	S-IVB Engine Cutoff-Start T4
	01.915	On	Any S-IVB Engine Cutoff
	01.555	Off	Switch Selector Read
	01.561	On	Switch Selector Zero
-5	52.898	Off	LOX Tank Vent Opened
	52.771	On	LOX Tank Vent Closed
	51.596	Off	LOX Tank Vent Closed
	51.567	On	LOX Tank Vent Opened
	48.010	Off	LH2 Tank Vent Open
	47.852	On	LH2 Tank Vent Closed
	46.932	Off	Fuel Tank Directional Vent Ground Position
	46.689	On	Fuel Tank Directional Vent Flight Position
	44.354	Off	Fuel Tank Directional Vent Flight Position
	44.130	On	Start Tank Depressurized
	44.128	On	Engine Control Power On
	43.512	On	Fuel Tank Directional Vent Ground Position
	41.736	Off	LH2 Tank Vent Closed
	41.710	On	LH2 Tank Vent Open
	41.485	On	Engine Ignition Power On
	41.479	On	Engine Systems Ready
	30.153	Off	Cold Heat/Exchanger CKT 1 VV Open
	30.151	On	Cold Heat/Exchanger CKT 1 VV Closed
	29.924	Off	Prelaunch Indication
	29.857	On	Launch Indication
	29.846	Off	EBW + RSCR TST Power On
	29.843	On	Close Start Bottle Vent
	29.246	Off	Start Tank Vent Open Command
	00.642	On	Maximum Level Sensors Wet
	00.642	On	Hi Level Sensors Wet
	00.642	On	Low Level Sensors Wet
-4			
-3	44.417	On	APS 2 System Ready
	44.417	On	APS Mod 2 Bus On
	44.416	On	APS Mod 1 Bus On
	44.416	On	APS 1 System Ready
	44.414	On	Auxiliary Propulsion System 2 OK
	44.412	On	APS Mod 1 + 2 Busses On
	44.412	On	Auxiliary Propulsion System 1 OK
	44.393	Off	APS Mod 1 + 2 Busses On
	44.393	Off	APS 2 System Ready
	44.393	Off	APS Mod 2 Bus On
	44.390	Off	Auxiliary Propulsion System 2 OK
	37.420	Off	S and A Safe
	37.403	On	S and A Armed
	37.398	On	Propellant Dispersion Ordnance Ready
	01.399	Off	APS Mod 1 Bus On
	01.399	Off	APS 1 System Ready

TIME MIN	TIME SEC	INDICATION	EVENT
-3	01.397	Off	Auxiliary Propulsion System 1 OK
	00.825		Hold
1708	00.494		
	01.494	On	APS 2 System Ready
	01.494	On	APS Mod 2 Bus On
	01.498	On	Auxiliary Propulsion System 2 OK
	01.499	On	APS Mod 1 Bus On
	01.499	On	APS 1 System Ready
REAL TIME GMT	01.503	On	APS Mod 1 + 2 Busses On
	01.503	On	All Systems Ready
	01.503	On	Auxiliary Propulsion System 1 OK
	01.505	On	S-IVB Systems Ready Indication
1712	11.709	Off	Ground Cold Helium Cross-Over Valve Opened
	11.713	On	Ground Cold Helium Cross-Over Valve Closed
	16.372	Off	Cold Helium Reg Backup PS EN
	33.929		Resume
-3	00.00		
-2	43.671	On	Launch Sequence Start
	43.511	Off	LOX Tank Vent Opened
	43.412	Off	Launch Sequence Ready Indication
	43.382	On	LOX Tank Vent Closed
	41.580	Off	LOX Tank Vent Closed
	41.578	On	LOX Tank Vent Closed
	28.213	On	LOX Tank PP + FC OK
	26.324	Off	LOX Fill and Drain Valve Opened
	25.841	On	LOX Fill and Drain Valve Closed
	24.943	Off	GN2 LOX Tank and US PBV Closed
	24.943	On	GN2 LOX Tank and UB PBV Opened
	19.180	Off	LOX Tank PP + FC CX
	17.790	On	LOX Tank PP + FC OK
-1	54.158	Off	LH2 Tank Vent Open
	53.993	On	LH2 Tank Vent Closed
	53.928	Off	Fuel Tank Prepressurization Supply Valve Closed
	53.924	On	Fuel Tank Prepressurization Supply Valve Opened
	52.342	Off	LH2 Tank Vent Closed
	52.336	On	LH2 Tank Vent Closed
	36.269	Off	LH2 Fill and Drain Valve Opened
	35.807	On	LH2 Fill and Drain Valve Closed
	35.164	Off	LH2 Umbilical Purge Supply Valve Closed
	35.160	On	LH2 Umbilical Purge Supply Valve Opened
	18.550	On	Fuel Tank Minimum Liftoff Pressure OK
-0	47.572	On	LH2 Tank Prepressurization OK
	47.482	Off	Fuel Tank Prepressurization Supply Valve Opened
	47.477	On	Fuel Tank Prepressurization Supply Valve Closed
	34.520	Off	LOX Tank Vent Closed
	34.244	On	LOX Tank Vent Closed
	29.401	Off	S-IVB Power External
	29.245	Off	Ready For 40141 Power
	29.231	Off	Fuel Tank Directional Vent Ground Position
	29.155	On	S-IVB Power Internal
	29.152	On	S-IVB Power Cross-over OK Indicated
	29.053	On	Fuel Tank Directional Vent Flight Position
	29.046	On	S-IVB Ready to Launch Indicated
	06.344	On	LVDA Firing Commit Enable
	04.356	Off	Fuel Tank Prepressurization Supply Vent Closed
	04.351	On	Fuel Tank Prepressurization Supply Vent Opened
	04.349	Off	Start Tank Supply Vent Closed
	04.344	On	Start Tank Supply Vent Open
	04.325	Off	Cold Helium Supply Vent Closed

TABLE 4-2 (Sheet 2 of 2)
GROUND SEQUENCE OF EVENTS

TIME MIN	TIME SEC	INDICATION	EVENT
-0	04.323	On	Cold Helium Supply Vent Opened
	04.323	Off	Start Tank Supply Valve Opened
	04.320	Off	Thrust Chamber Chilldown Valve Opened
	04.320	Off	Start Bottle Pressurizing
	04.319	On	Start Tank Supply Valve Closed
	04.315	On	Thrust Chamber Chilldown Valve Closed
	04.309	Off	Engine Cont Helium Bottle Valve Closed
	04.308	On	Engine Cont Helium Supply Valve Closed
	04.307	On	Engine Cont Helium Bottle Valve Opened
	04.299	On	Cold Helium Supply Closed
	04.164	Off	Stage Control Helium Supply Opened
	04.151	On	Stage Control Helium Supply Closed
	04.063	Off	Cold Helium Supply Opened
	03.179	Off	Engine Control Helium Supply Valve Opened
	01.961	On	Cold Helium CKT Crossover PS Made
	01.412	On	Time for Commit Indication
	01.406	On	Commit Indication
	01.401	Off	Launch Indication
	01.401	Off	Ready for 4D119 Power
	01.401	Off	Ready for S-IVB Power
	01.401	Off	Time for Commit Indication
	01.401	Off	Launch Seq Start
	01.395	Off	Flight Sequence Zero Indication
	01.393	Off	Engine Start Relay Reset
	01.393	Off	APS Mod 1 + 2 Busses On
	01.393	Off	APS Mod 1 Bus On
	01.393	Off	Sequence Bus Power On
	01.393	Off	Liquid Level Sensors Power On
	01.393	Off	Engine Control Power On
	01.393	Off	Engine Ignition Power On
	01.393	Off	PU Power On
	01.393	Off	APS 1 OX Tank 100 Percent Full
	01.393	Off	APS 2 OX Tank 100 Percent Full
	01.933	Off	APS 1 Fuel Tank 100 Percent Full
	01.393	Off	APS 2 Fuel Tank 100 Percent Full
	01.393	Off	APS 1 System Ready
	01.393	Off	APS 2 System Ready
	01.393	Off	APS Mod 2 Bus On
	01.393	Off	APS 1 Helium Reg Normal
	01.393	Off	APS 2 Helium Reg Normal
	01.393	Off	LH2 Prevalve Closed
	01.393	Off	LOX Prevalve Closed
	01.393	Off	Auxiliary Hydraulic Pump Motor On
	01.393	Off	Ground and Coast Relay Reset
	01.593	Off	Hydraulic System Ready
	01.393	Off	Engine Systems Ready
	01.393	Off	LOX Tank Vent Closed
	01.393	Off	LOX Tank PP + FC OK
	01.393	Off	LH2 Tank Vent Closed
	01.393	Off	LOX Flight P+C Per Reset
	01.393	Off	Fuel Tank Minimum Liftoff Pressure OK
	01.393	Off	LH2 Tank Prepressurization OK
	01.393	Off	Fuel Tank Directional Vent Flight Position
	01.393	Off	Flight SCO Group On
	01.393	Off	Flight MXR Group On
	01.393	Off	Orbit XMTR Group On
	01.393	Off	Flight XMTR Group On
	01.393	Off	SSB Group On
	01.393	Off	SSB Transmitter On
	01.393	Off	Inflight Relays On

TIME MIN	TIME SEC	INDICATION	EVENT
-0	01.393	Off	Record Measurement Group On
	01.393	Off	RSCR 1 Signal Blocked
	01.393	Off	RSCR 2 Signal Blocked
	01.392	Off	Ullage Rockets Relay Resey
	01.392	Off	S and A Armed
	01.392	Off	Any S-IVB Engine Cutoff
	01.391	Off	LOX FF Cutoff Sensor Wet
	01.391	Off	LOX Recirculation Valves On
	01.391	Off	Hydraulics OK
	01.391	Off	LH2 Recirculation Pump Engine
	01.389	Off	LOX Fill and Drain Valve Closed
	01.389	Off	LH2 Fill and Drain Valve Closed
	01.389	On	LOX overfill Sensors Wet
	01.389	On	LH2 Overfill Sensors Wet
	01.389	Off	All Systems Ready
	01.389	Off	Auxiliary Propulsion System 1 OK
	01.389	Off	Auxiliary Propulsion System 2 OK
	01.389	Off	Recirculation OK
	01.389	Off	Switch Selector Zero
	01.389	Off	Telemetry Ready
	01.389	Off	Ready for Seq Pt Indication
	01.389	Off	Prop Disp Ordance Ready
	01.388	Off	DRSCR No. 1 Power On
	01.387	Off	S-IVB Power Internal
	01.387	Off	PU Ready
	01.387	Off	Start Tank Pressurized
	01.387	Off	PU System Ready
	01.387	Off	RSCR 1 on Internal Power
	01.387	Off	RSCR 2 On Internal Power
	01.387	Off	S-IVB Systems Ready Indication
	01.386	Off	DRSCR No. 2 Power On
	01.385	Off	S-IVB Ready for Power XFER
	01.385	Off	4D10 Bus On
	01.385	Off	4D20 Bus On
	01.385	Off	4D30 Bus On
	01.385	Off	4D40 Bus On
	01.385	Off	S-IVB Power XFER OK Indication
	01.251	Off	4D31 SUPV Network 1 OK
	01.250	Off	4D11 SUPV Network 3 OK
	01.248	Off	Networks OK
	01.245	Off	S-IVB Ready to Launch Indication
	01.226	Off	4D21 SUPV Network 2 OK
	01.221	Off	4D41 SUPV Network 4 OK
	01.218	Off	LH2 Umbilical Purge Supply Valve Open
	01.214	On	LH2 Umbilical Purge Supply Valve Closed
	01.153	Off	GN2 LOX Tank and Umbilical PBV Opened
	01.148	On	GN2 LOX Tank and Umbilical PBV Closed
	01.146	On	Liftoff Switch No. 2 Indication
	01.145	On	LIftoff Switch No. 1 Indication
	01.088	On	Liftoff Indication
	01.088	Off	LVDA Firing Commit Enable
	01.086	On	IU Liftoff Indication
	01.035	Off	All Plugs Connected
	01.031	Off	LVDA Firing Commit Enable
	01.027	On	IU Liftoff Indication
	00.704	Off	LH2 Umbilical Purge Supply Valve Closed
	00.701	On	LH2 Umbilical Purge Supply Valve Opened
	00.588	Off	LOX Debris Valve Open
	00.330	On	LOX Debris Valve Closed
	00.271	Off	LH2 Debris Valve Opened

TIME MIN	TIME SEC	INDICATION	EVENT
	00.133	Off	GN2 LOX Tank and Umbilical PVB Closed
	00.130	On	GN2 LOX Tank and Umbilical PVB Opened
0	00.000		
	00.346	Off	Cold Helium OK For 3000 PR
	00.554	On	LH2 Debris Valve Closed
	05.422	Off	Liftoff Switch No. 1 Indication
	05.602	Off	Liftoff Switch No. 2 Indication

5. COUNTDOWN OPERATIONS

The launch day countdown was initiated at 0330 GMT on 25 August 1966 and culminated in a successful liftoff at 1715:32.960 GMT on the afternoon of the same day.

The countdown, including four holds lasting 2 hr 24 min 33 sec, was completed in 13 hr 45 min. The S-IVB portion of the countdown proceeded satisfactorily and all stage systems responded correctly to commands. A countdown demonstration test (CDDT) was satisfactorily conducted between 2 and 8 August.

The countdown is reviewed and evaluated in the following paragraphs which include discussions of the preflight checkouts, purges, propellant and helium loading, and the terminal countdown.

5.1 Propulsion System Checkouts

Preflight checkouts of the S-IVB-202 stage were initiated on 14 March 1966 after the stage was erected at the Florida Test Center (FTC). The handling and checkout requirement drawings used in vehicle checkout are listed in Douglas Report No. SM-47465, Narrative End Item Report on Saturn S-IVB/IB-202. The propulsion subsystem leak and functional test preparations were extended over a considerable period of time due to computer downtime and schedule interference with the AS-203 checkout and launch. Checkouts progressed smoothly, however, in spite of these delays.

5.2 Launch Vehicle Tests

After the S-IVB-202 stage was erected at Complex 34 on 11 March 1966, the following launch vehicle tests were conducted:

Title	Douglas or NASA Procedure	Date
Launch vehicle (L/V) switch selector functional test	7-LLVIB-201	22 March
L/V power transfer test	I-LLVIB-202A	25 March 18 May

Title	Douglas or NASA Procedure	Date
L/V emergency detection system test	7-LLVIB-210	30 March 13 July
S-IVB full pressure test	1B61597A	19 April
L/V flight sequence and EBW functional test	7-LLVIB-203A	22 April
L/V switch selector functional test	7-LLVIB-215	26 April
L/V sequence malfunction tests	7-LLVIB-204	26-27 April 12-18-20 May 14 July
L/V systems plugs in overall test (OAT)	7-LLVIB-211B	28 April 15 July
J-2 engine sequence test	1B61817	16-18 May 6 June
Space vehicle (S/V) systems OAT - plugs in	7-LSVIB-202A	23 July
S/V systems plug drop test	7-LSVIB-203A	26-27-28 July
Countdown demonstration test	7-LSVIB-203A3	2-3-7-8 August
Flight readiness test	7-LSVIB-204A	16 August
APS loading and firing	1A90592E 6-LSVIB-203	21 August

5.3 Countdown Demonstration Test

The countdown demonstration (CDDT) test was conducted in two parts. T -1 day operations were completed on 2 and 3 August. The T -0 operations, however, were delayed 4 days due to spacecraft problems and were performed on 7 and 8 August. The objective of this test was to perform an operation in the same sequence as the launch countdown to verify hardware and personnel compatibilities; to verify full system radio frequency (RF) compatibility, and to complete space vehicle alignment. Stage ordnance was installed during the test and left in with shorting plugs after completion.

Minor discrepancies occurred in both LH2 and LOX automatic loading systems, but neither presented a problem, and the countdown was not

delayed. The stage pneumatic sphere could not be brought up to nominal pressure because of excessive system usage. This situation was corrected subsequent to the CDDT by the installation of a larger supply orifice.

Two terminal countdowns were required to complete the test. The first count was aborted at T -4 min 30 sec because of difficulty in the spacecraft. The count was recycled and picked up at T -15 min. All systems performed flawlessly during the second terminal count, and liftoff conditions were attained without apparent difficulty.

During the S-IVB LOX detanking the LOX tank ullage pressure indication developed an $\pm$2.9 psi oscillation which damped out erratically over a period of time. This situation has been noted previously on this and other stages, and is presumed to have been caused by a slug of LOX in the pressure sensing line. To prevent the recurrence of this phenomena, a helium purge of the sensing line was installed prior to the launch countdown.

5.4 AS-202 Launch Countdown

The major portions of part 1 of the countdown (T -1 day) were accomplished during the CDDT. Therefore, the only S-IVB preparations were verification walkarounds, ordnance installation and hookup, final PU calibration, and propulsion checks.

The 12 hr T -0 day countdown was started at 0330 GMT on 25 August 1966. The guidance computer caused considerable delay in the count during the power transfer test at 0600 GMT, but the S-IVB portion of the countdown progressed smoothly. The countdown was satisfactorily terminated in a successful liftoff at 1715:32.960 GMT. The following paragraphs present a discussion of significant prelaunch preparations.

5.4.1 Auxiliary Propulsion System Preparations

Auxiliary propulsion system (APS) preparations for launch consisted of transfer system purges, propellant loading, and engine confidence firing. The preparations were accomplished on 21 August 1966, 4 days prior to launch.

5.4.1.1 APS Purges

Before loading was initiated, a GN2 purge was performed on the fuel and oxidizer transfer and return lines. The purge was supplied from the module 436 pneumatic console and was continued until gas samples contained less than 24 ppm of moisture.

5.4.1.2 APS Propellant Loading

APS module fuel and oxidizer loadings were initiated after the propellants had been recirculated to remove any trapped GN2. Loading data are presented in table 5-1.

The module helium spheres were pressurized to 3,000 psia. The modules were loaded as follows:

Item	Module 1		Module 2	
	Fuel	Oxidizer	Fuel	Oxidizer
Lockup pressure (psig)	29.0	32.0	29.0	32.0
Average fill rate (in./min)	1.21	1.28	1.15	1.16
Quantity loaded (in.)	9.88	9.90	9.85	9.89

5.4.1.3 Confidence Firing

The APS confidence firing was accomplished in accordance with NASA procedure 6-LSVIB-203. The engines were fired in the following sequence:

Sequence	Engine
Minus pitch	III_p
Minus roll	I_{IV} and III_{II}
Plus pitch	I_p
Plus roll	I_{II} and III_{IV}

Each sequence consisted of one 250-ms clearing pulse and two 65-ms pulses with a 750-ms delay between each pulse.

Analysis of the firing data indicated that the engine chamber pressure specifications were met and that the systems were acceptable for flight.

5.4.2 Prelaunch Purging

The oxidizer, fuel, engine, and nonpropulsive vent (NPV) systems on the S-IVB stage were purged with helium in accordance with Douglas procedure.

5.4.2.1 Oxidizer System Purges

The LOX tank was purged by flowing ambient helium into the tank through the fill and drain valve and out of the tank through the LOX umbilical line drain valve. While the LOX tank was being purged, two 5-min engine LOX system purges were initiated. The first 5 min consisted of purging the LOX system upstream of the main LOX valve and through the bleed valve. This helium purge was supplied from the propulsion cart connected to the port on the engine inlet pressure transducer sandwich flange. The second 5-min purge was completed with the bleed valve closed and the main LOX valve open, thus purging the LOX injector. When the 10 min of engine LOX system purge was complete, and a LOX tank gas sample contained less than 200 ppm moisture and greater than 80 percent helium, a cyclic purge of the LOX tank was initiated. The prevalve, recirculation valve, and the bleed valve were opened. The fill and drain valve and the main LOX valve were closed. The LOX tank was then pressurized to 30 $\pm$1 psia and vented to ambient three times.

5.4.2.2 Fuel System Purge

The LH2 tank purge was initiated with the fill and drain valve, the umbilical vent valve, and the LH2 tank prepressurization supply open. Before purging was initiated, the LOX tank was pressurized to 30 $\pm$1 psia and the prevalve and recirculation valve were closed. Concurrently with the initial tank purge, the engine fuel system was purged for 30 min through the bleed valve. A 5-min fuel injector purge was then initiated by closing the bleed valve and opening the main fuel valve. The augmented spark ignition LOX system was also purged at this time. The engine propellant system purge equipment was then secured. When the LH2 tank gas

sample, obtained at the propellant disconnect monitor port, indicated a helium content of greater than 99 percent and a moisture content of less than 200 ppm, the LH2 tank cyclic purge was initiated. The LH2 tank was vented to ambient and the prevalves and recirculation valves opened. The LH2 tank fill and drain valves were closed and the LH2 tank was pressurized to 28 ±1 psia. The prevalves and recirculation valves were then closed, and the tank vented to ambient. The cycle was performed three times.

5.4.2.3 Engine Pump Purge

The S-IVB engine pump purge and LOX dome purge were enabled for a minimum of 15 min at the initiation of S-IB LOX fast fill (22 percent S-IB level). The engine thrust chamber purge was also initiated at this time and was continued until S-IVB LH2 loading.

5.4.2.4 LOX Recirculation Pump Cavity Purge

The LOX recirculation pump cavity purge was initiated at 22 percent S-IB LOX load. The cavity purge was terminated prior to initiation of S-IVB LOX loading at which time the recirculation pump cavity was pressurized.

5.4.3 Loading

5.4.3.1 LOX Loading

The S-IVB LOX loading was initiated at 1313:20 GMT and was automatically controlled by the propellant tanking computing systems (PTCS). The LOX tank pressure reached a maximum of 33.8 psia during transfer line chilldown and 26.0 psia during initial fill to the 7.5 percent level. The LOX was loaded in the following phases:

Phase	Desired Fill Level (%)	Average Rate (gpm)
Initial fill	0 to 7.5	500
Fast fill	7.5 to 98	775
Slow fill	98 to 100	220

Automatic replenish was initiated at the 100 percent level and continued until LOX tank pressurization. The replenish operation was manually controlled during the automatic launch sequence.

During the initial part of the loading a problem was encountered with the LOX chilldown pump motor container purge (paragraph 13.3), but this had no adverse affect on the loading.

5.4.3.2 LH2 Loading

LH2 loading was initiated at 1452:53 GMT and was automatically controlled by the PTCS. The LH2 was loaded in the following phases:

Phase	Desired Fill Level (%)	Average Rate (gpm)
Slow fill	0 to 6	360
Fast fill	6 to 96	2,520
Slow fill	96 to 100	325

When the 100 percent level was reached, automatic replenish was initiated to compensate for boiloff and maintain the fuel level. The transition from slow to fast fill was smoothly accomplished.

5.4.3.3 Stage Pneumatics Loading

All S-IVB stage pneumatic spheres were satisfactorily loaded before launch. Prior to the initiation of LH2 loading, the cold helium spheres installed in the LH2 tank were prepressurized to approximately 700 psia from the GSE cold gas system to prevent them from collapsing as they cooled during the initial part of LH2 loading. The loading levels and time requirements are presented in table 5-2.

5.5 Environmental Control System

The aft skirt purge and thermoconditioning system was started prior to LOX loading and was operated continuously until liftoff. The system functioned properly during the countdown maintaining APS temperatures within the design limits of 87 $\pm$5 deg F. At liftoff, the APS temperature was 87 deg F.

5.6 Terminal Countdown

The engine was satisfactorily conditioned for launch during the terminal countdown with all systems reaching their liftoff requirements (tables 5-3 and 5-4). One hold was called at T -3 min due to a lower than desired RP-1 level in the S-IB stage. The hold was released after approximately 4.5 min and the count was picked up at T -3 min with no detrimental effect on engine conditioning.

Turbopump chilldown, for both LOX and LH2, began at T -10 min. The chilldown pump developed head was approximately 6.7 psid for LH2 and 6.5 psid for LOX. The chilldown flowrate (pressurized) at liftoff was 147.5 gpm for LH2 and 44 gpm for LOX (paragraphs 11.2 and 10.4). The liftoff requirements were satisfactorily met for both fuel and oxidizer systems.

Thrust chamber chilldown and engine start sphere chilldown were initiated at T -15 min and T -14 min 30 sec, respectively. Start sphere pressurization occurred at T -5 min 30 sec. Sphere pressure and temperature were 1,269 psia and 286 deg R at liftoff.

The engine control sphere was pressurized at T -30 min and was chilled satisfactorily by start sphere chilldown. The sphere pressure at liftoff was 2,900 psia.

The launch vehicle automatic launch sequence was initiated at 1713:00.258 GMT with the start of S-IVB LOX tank prepressurization. The LOX tank pressurized signal was received after an elapsed time of 15 sec. The LH2 tank prepressurization began at T -114.2 sec with the pressurized status occurring 68 sec later. S-IVB "ready-for-launch" was received at T -29.046 sec.

5.7 Holds

The countdown was interrupted by four holds totaling 2 hr 24 min 33 sec. The countdown was also advanced 48 min at one time in an effort to meet the scheduled launch time. The following is a tabulation of countdown interruptions:

Countdown Time	Duration	Remarks
T -9 hr 5 min	60 min	Guidance computer problem
T -8 hr 24 min 30 sec	39 min	To allow operations to catch up with the clock
T -6 hr 48 min	---	Countdown advanced 48 min
T -26 min	41 min	Tracking ship difficulties
T -3 min	4 min 33 sec	S-IB stage fuel level low

5.8 Launch Environment

Specific weather conditions 3 mi due south of pad 34 at KSC during launch were as follows:

Ambient temperature	86.0	deg F
Dewpoint	75	deg F
Relative humidity	70	percent
Wind direction	170	deg from North
Wind velocity	10	knots
Total cloud coverage	7	percent
Barometric pressure	30.0	in. of mercury

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TABLE 5-1
APS PROPELLANT LOADED

PROPELLANT	INDICATED BELLOWS EXTENSION (in.)	INDICATED PROPELLANT TEMPERATURE (°F)	PUBLISHED LIMIT (in.)	REMARKS
		Before Pressurization		
Oxid No. 1	9.90	80.5	6.00/10.00	Corrected, data high
Fuel No. 1	9.88	80.5	6.00/10.00	Corrected, data high
Oxid No. 2	9.89	82.5	6.00/10.00	Corrected, data high
Fuel No. 2	9.89	80.5	6.00/10.00	Corrected, data high
		After Pressurization Before Data Shift		
Oxid No. 1	9.84	80.5	6.00/10.00	OK
Fuel No. 1	9.85	80.5	6.00/10.00	OK
Oxid No. 2	9.85	82.5	6.00/10.00	OK
Fuel No. 2	9.87	80.5	6.00/10.00	OK
		After Data Shift and Before Firing		
Oxid No. 1	10.00	82.5	6.00/10.00	OK
Fuel No. 1	10.00	82.5	6.00/10.00	OK
Oxid No. 2	9.98	84.5	6.00/10.00	OK
Fuel No. 2	10.00	82.5	6.00/10.00	OK
		Pressurized and After Firing		
Oxid No. 1	9.90	82.5	6.00/10.00	OK
Fuel No. 1	9.91	82.5	6.00/10.00	OK
Oxid No. 2	9.88	84.5	6.00/10.00	OK
Fuel No. 2	9.93	82.5	6.00/10.00	OK

TABLE 5-2
LAUNCH SYSTEM PRESSURIZATION SUMMARY

SYSTEM	FINAL SYSTEM PRESSURIZATION			PRESSURE AT T -15 SEC (psia)
	PREPRESS. LEVEL (psia)	PRESSURIZED LEVEL (psia)	TIME REQUIRED (min:sec)	
Cold helium spheres	1,160	3,040	13:00	3,070
Stage pneumatic spheres	1,420	2,960	00:16	2,880
Engine pneumatic sphere	1,340	2,950	00:10	2,960
Engine start sphere	1,052	1,255	00:08	1,265
LH2 tank	16.1	36.5	01:08	37.1
LOX tank	16.2	40.2	00:15	43.0

TABLE 5-3
LAUNCH ENGINE CONDITIONING SUMMARY

SYSTEM	T -15 min	T -10 min	T -5 min	T
Fuel Pump Inlet				
Chill flowrate, gpm	0	85	89	138
Pressure, psia	17.0	25.0	25.0	44.6
Temperature, deg R	39.45	40.80	40.52	39.91
Oxidizer Pump Inlet				
Chill flowrate, gpm	0	41.1	41.1	47.6
Pressure, psia	23.1	29.9	29.9	58.5
Temperature, deg R	168.30	165.48	165.55	165.62
Thrust Chamber				
Jacket temperature, deg R	381	250	218	215
Engine Start Sphere				
Pressure, psia	1,050	1,055	1,265	1,265
Temperature, deg R	275	263	283	286
Engine Control Sphere				
Pressure, psia	2,910	2,890	2,910	2,960
Temperature, deg R	338	286	283	288

NOTE: All time references are based on actual time as opposed to countdown clock time.

TABLE 5-4
TERMINAL COUNTDOWN SEQUENCE - S-IVB-202 FLIGHT

ITEM NO.	FUNCTION	ACTUAL TIME FROM RO* (sec)
1	Thrust chamber purge OFF	-1,173
2	Thrust chamber chill ON	-1,173
3	Start sphere purge OFF	-1,143
4	Start sphere chill ON	-1,143
5	LOX chill pump ON	-873
6	LH2 chill pump ON	-870
7	LOX and LH2 prevalves CLOSED	-864
8	Start sphere pressure ON	-603
9	Heat exchanger crossover valve CLOSED	-202
10	Cold helium regulator DISABLED	-197
11	LOX tank vent valve CLOSED	-163
12	LOX tank pressurization command	-163
13	LOX fill and drain valve CLOSED	-146
14	LH2 tank vent valve CLOSED	-114
15	LH2 tank prepressurization command	-114
16	LH2 fill and drain valve CLOSED	-96
17	Power transfer to INTERNAL	-29
18	Directional LH2 vent to flight position	-29
19	Thrust chamber chilldown OFF	-4.3
20	Engine control sphere pressurization OFF	-4.3
21	Engine start sphere pressurization OFF	-4.3
22	Cold helium fill OFF	-4.3
23	Stage control helium pressurization OFF	-4.1
24	APS helium pressurization OFF	-4.1
25	Range Zero	1715.32 GMT

*Items prior to -180 sec will not correlate with countdown time due to a 273-sec hold at that time.

6. TRAJECTORY

The AS-202 actual trajectory was close to predicted and well within stage design conditions. This section presents a discussion of the AS-202 vehicle actual trajectory and compares it with the preflight and postflight predicted trajectories. In general, the MSFC predicted trajectory is used when comparisons are made with the S-IB stage actual trajectory parameters, and the DAC predicted trajectory is used when comparisons are made with the S-IVB stage actual trajectory parameters.

6.1 Comparison between Actual and Preflight Predicted Trajectories

A comparison was made between the actual trajectory, based on tracking and telemetry data, and the preflight predicted trajectory. The S-IB stage predicted trajectory is presented in NASA Technical Memorandum NASA TM X-53470, AS-202 Launch Vehicle Operational Flight Trajectory, dated 3 June 1966, and the S-IVB stage portion of the predicted trajectory is presented in DAC Report No. SM-46975B, S-IVB-202 Stage Flight Test Plan, dated 15 August 1966.

The AS-202 actual trajectory was close to that predicted. Figure 6-1 shows the trajectory profile and trace for the actual and predicted trajectories. Figures 6-2 and 6-3 show the earth-fixed velocity, earth-fixed velocity vector elevation angle, and axial acceleration during S-IB stage powered flight. Dynamic pressure and Mach number histories shown in figure 6-4 did not differ significantly from predicted. Figure 6-5 presents the pitch and yaw angle of attack histories. Table 6-1 summarizes the conditions existing at the time of maximum dynamic pressure. Wind environment during boost, figure 6-6, was substantially less than design values.

Conditions at S-IB/S-IVB separation differed considerably from those predicted due to high S-IB stage performance. Table 6-2 indicates the following at S-IVB stage first motion: vehicle range was 1,700 ft longer than predicted, vehicle velocity was 77.9 ft/sec greater than predicted, altitude was 8,606 ft higher than predicted, and burntime was 1.35 sec less than predicted.

Figures 6-7 through 6-9 show S-IVB stage inertial velocity, axial acceleration, inertial velocity vector azimuth angle, inertial velocity vector elevation angle, crossrange position, and crossrange velocity. As shown in figure 6-7, the actual vehicle velocities and axial accelerations were higher than predicted. These were produced by a higher-than-predicted thrust and later-than-predicted engine mixture ratio cutback.

Trajectory conditions at S-IVB engine cutoff are summarized in table 6-3. At S-IVB engine cutoff, the vehicle range was 125,724 ft shorter than predicted, inertial vehicle velocity was 0.8 ft/sec greater than predicted, altitude was 100 ft lower than predicted, and burntime was 13.05 sec less than predicted. These values were within three-sigma tolerances. A tabulation of the actual trajectory is included in appendix 6. Table 6-3 also presents conditions at S-IVB/CSM separation; while table 6-4 presents the earth-intersecting conic elements at insertion. Table 6-3 shows that the velocity at S-IVB/CSM separation was 10.7 ft/sec higher than predicted. This deviation was due to an actual J-2 engine cutoff impulse which was higher than that used in the DAC predicted trajectory.

6.2 Postflight Predicted Trajectory Analysis

A six-degrees-of-freedom flight simulation computer program generated two trajectories for the S-IVB-202 stage flight-trajectory evaluation. The first is the preflight predicted trajectory discussed in the previous section. The second is a trajectory simulated after the flight with the S-IVB stage initial conditions being a point on the actual trajectory at the time of S-IVB stage first motion. This postflight predicted trajectory simulation is useful in flight evaluation since it shows where the S-IVB stage would have flown had all systems performed as predicted. Compared to the postflight predicted trajectory, the actual S-IVB stage trajectory may be characterized briefly as fast, high, and long.

Figures 6-10 through 6-12, show the differences between the actual and postflight predicted trajectories for several key parameters. Also included are the differences between the actual and preflight predicted trajectories.

The conditions at S-IB/S-IVB separation were faster, higher, and more downrange than predicted. During S-IVB powered flight, the actual velocity was higher than predicted (figure 6-10). This was caused by a higher acceleration history resulting from the higher-than-predicted S-IVB thrust and mass flowrate. As noted previously, the velocity at guidance cutoff was close to predicted. The difference between the predicted and actual altitude histories during S-IVB flight (figure 6-10) can be explained by the combination of high initial altitude and velocity and the guidance system commanding a lower trajectory as a result of the higher-than-predicted S-IVB acceleration. The guidance system steered the vehicle to the desired altitude at S-IVB engine cutoff. Ground range differences are shown in figure 6-11. Compared with the post-flight predicted history, the actual ground range was long throughout flight due to higher-than-predicted S-IVB acceleration and flatter-than-predicted commanded vehicle attitude. Differences between predicted and actual crossrange position, inertial velocity vector elevation angle, and inertial velocity vector azimuth angle were smaller as shown in figures 6-11 and 6-12.

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p. 72

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TABLE 6-1
AS-202 CONDITIONS AT MAXIMUM DYNAMIC PRESSURE

PARAMETER		UNITS	MSFC PREDICTED	ACTUAL	DEVIATION*
Range time	(t)	sec	79.7	79.5	-0.2
Dynamic pressure	(q)	lb/ft^2	659.0	669.3	10.3
Altitude	(h)	ft	41,304	44,047	2,743
Freestream velocity	(V_{RM})	ft/sec	1,483.4	1,564.0	80.6
Mach number	(M)	--	1.53	1.63	0.10
Ambient pressure	(P_a)	lb/ft^2	398.2	358.8	-39.4
Pitch angle of attack	(α_P)	deg	-0.06	-0.44	-0.38
Yaw angle of attack	(α_Y)	deg	0.04	0.53	0.48

* Deviation is actual minus predicted.

TABLE 6-2
AS-202 CONDITIONS AT S-IVB FIRST MOTION

PARAMETER		UNITS	MSFC PREDICTED	ACTUAL	DEVIATION*
Range time	(t)	sec	145.4	144.33	-1.15
Downrange distance	(X_E)	ft	189,152	190,642	1,490
Vertical distance	(Y_E)	ft	184,279	192,992	8,713
Crossrange distance	(Z_E)	ft	357	-3,223	-3,580
Downrange velocity	($\dot{X}_E$)	ft/sec	5,265.8	5,274.3	8.5
Vertical velocity	($\dot{Y}_E$)	ft/sec	3,054.3	3,192.5	138.2
Crossrange velocity	($\dot{Z}_E$)	ft/sec	8.6	-27.5	-36.1
Relative velocity	(V_E)	ft/sec	6,087.5	6,165.4	77.9
Inertial velocity	(V_I)	ft/sec	7,251.4	7,320.5	69.1
Inertial flight path elevation angle	(γ_{1_I}')	deg	25.37	26.30	0.93
Inertial flight path azimuth angle	(γ_{2_I}')	deg	102.157	101.840	-0.317
Altitude	(h)	ft	185,246	193,852	8,606
Range	(S)	ft	187,090	188,790	1,700

* Deviation is actual minus predicted.

TABLE 6-3
AS-202 TRAJECTORY CONDITIONS

PARAMETER	UNIT	AT S-IVB ENGINE CUTOFF			AT S-IVB/CSM SEPARATION		
		DAC PREDICTED	ACTUAL	DEVIATION*	DAC PREDICTED	ACTUAL	DEVIATION*
Range time (t)	sec	601.52	588.47	-13.05	611.5	600.0	-11.5
Downrange distance (X_E)	ft	5,354,507	5,228,488	-126,019	5,560,641	5,466,500	-94,141
Vertical distance (Y_E)	ft	39,570	71,273	31,703	1,340	28,388	27,048
Crossrange distance (Z_E)	ft	125,564	121,336	-4,228	132,264	129,019	-3,246
Downrange velocity ($\dot{X}_E$)	ft/sec	20,641.1	20,663.3	22.2	20,578.0	20,604.6	26.6
Vertical velocity ($\dot{Y}_E$)	ft/sec	-3,692.0	-3,571.4	120.6	-3,955.4	-3,872.6	82.8
Crossrange velocity ($\dot{Z}_E$)	ft/sec	664.1	659.4	-4.7	675.6	672.3	-3.3
Relative velocity (V_E)	ft/sec	20,979.2	20,980.0	0.8	20,965.6	20,976.1	10.5
Inertial velocity (V_I)	ft/sec	22,309.8	22,310.6	0.8	22,297.2	22,307.9	10.7
Inertial flight path elevation angle (γ_{1_I}')	deg	3.995	3.986	-0.009	3.821	3.799	-0.022
Inertial flight path azimuth angle (γ_{2_I}')	deg	111.986	111.844	-0.142	112.224	112.118	-0.006
Altitude (h)	ft	712,810	712,710	-100	727,828	729,994	2,166
Range (S)	ft	5,233,291	5,107,567	-125,724	5,435,524	5,340,847	-94,677

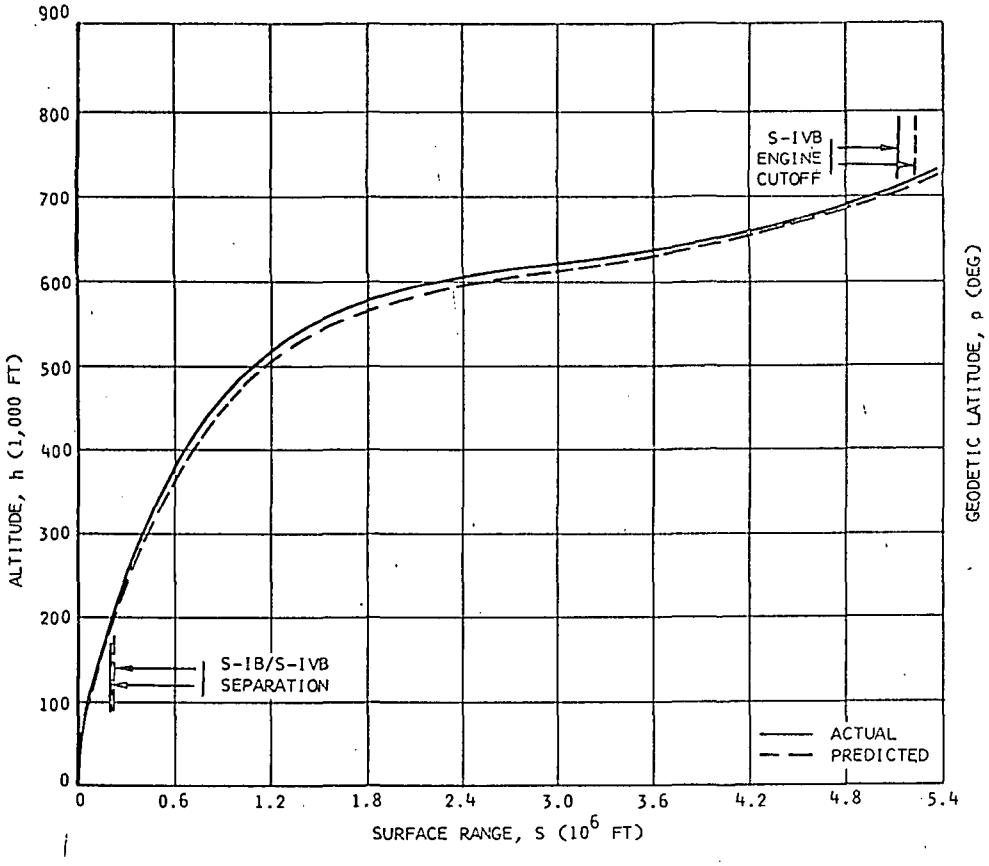
* Deviation is actual minus predicted.

TABLE 6-4
AS-202 EARTH-INTERSECTING CONIC ELEMENTS AT INSERTION

PARAMETER		UNITS	DAC PREDICTED	ACTUAL	DEVIATION*
Range time	(t)	sec	611.52	598.47	-13.05
Inclination	(i)	deg	31.7563	31.7619	0.0056
Eccentricity	(e)	---	0.2443	0.2436	-0.0007
Apogee altitude**	h(AP)	nmi	145.95	146.04	0.09

* Deviation is actual minus predicted.

** Based on an average earth radius of 3441.15 nmi



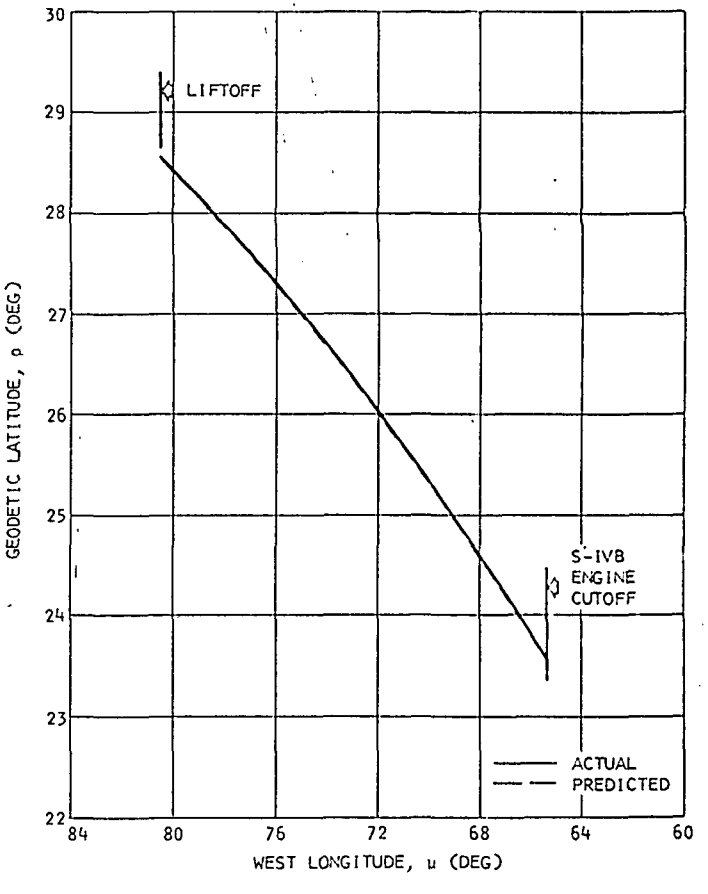


Figure 6-1. Trajectory Profile and Trace

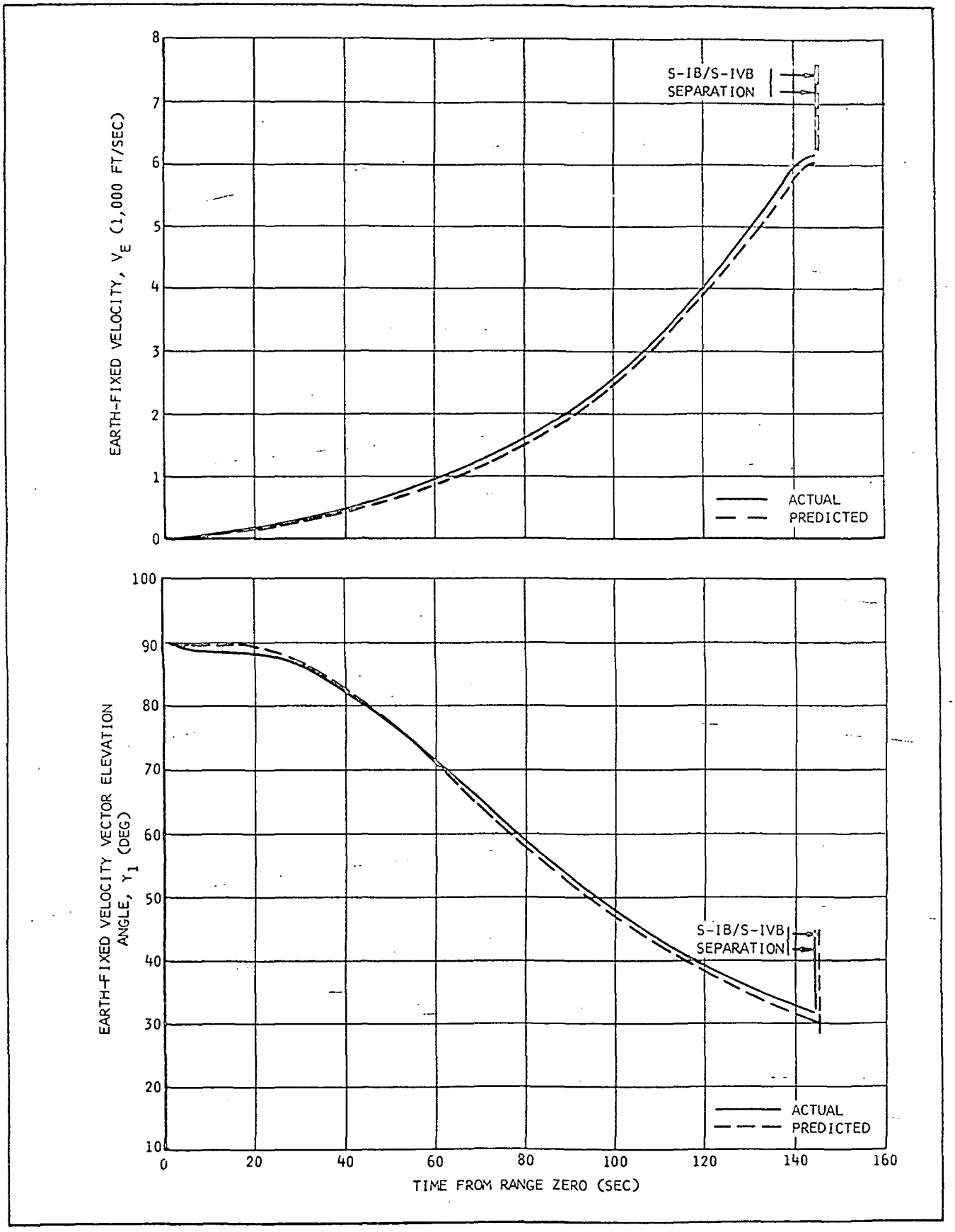


Figure 6-2. S-IB Stage Flight Earth-Fixed Velocity Vector Elevation Histories

24 October 1966

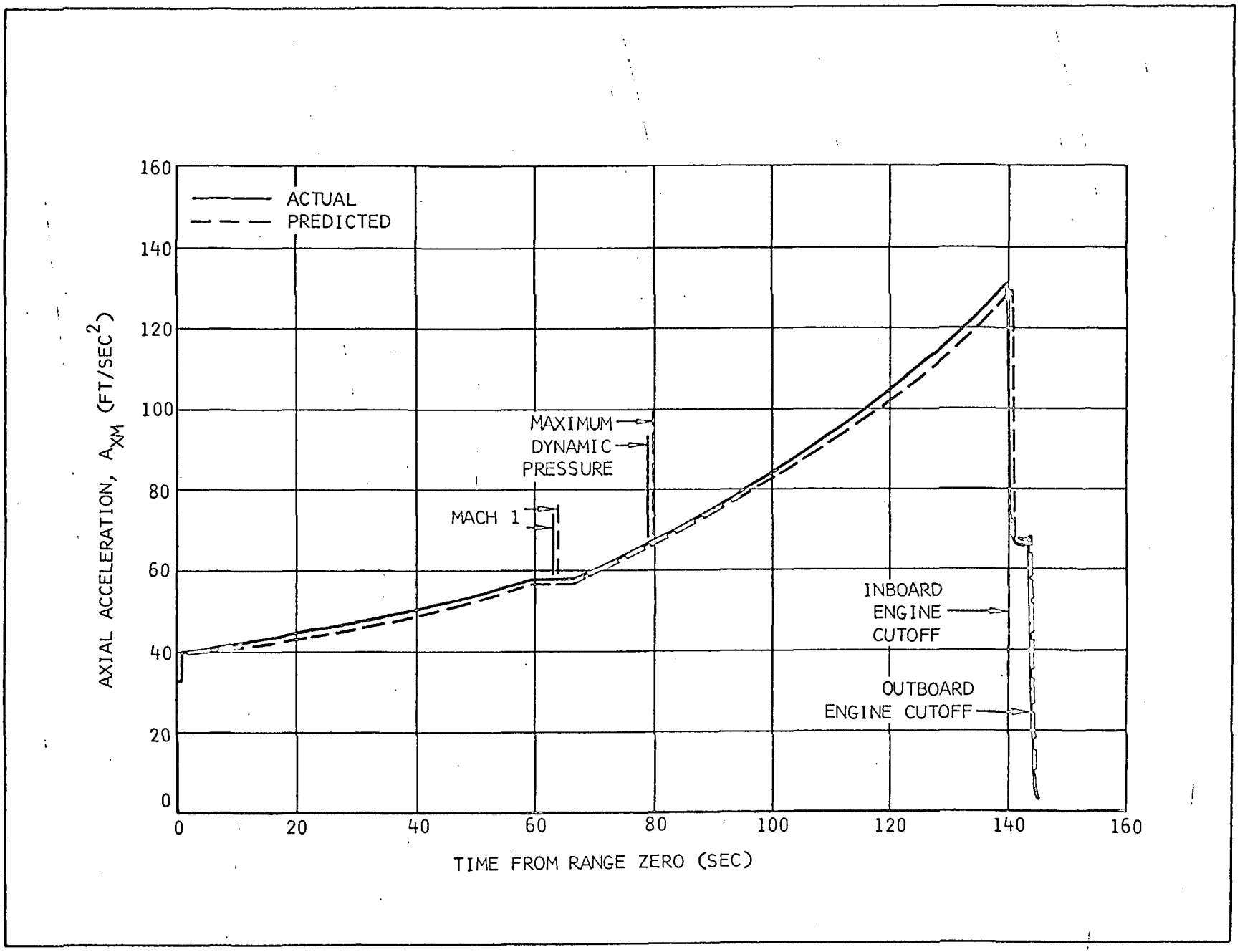
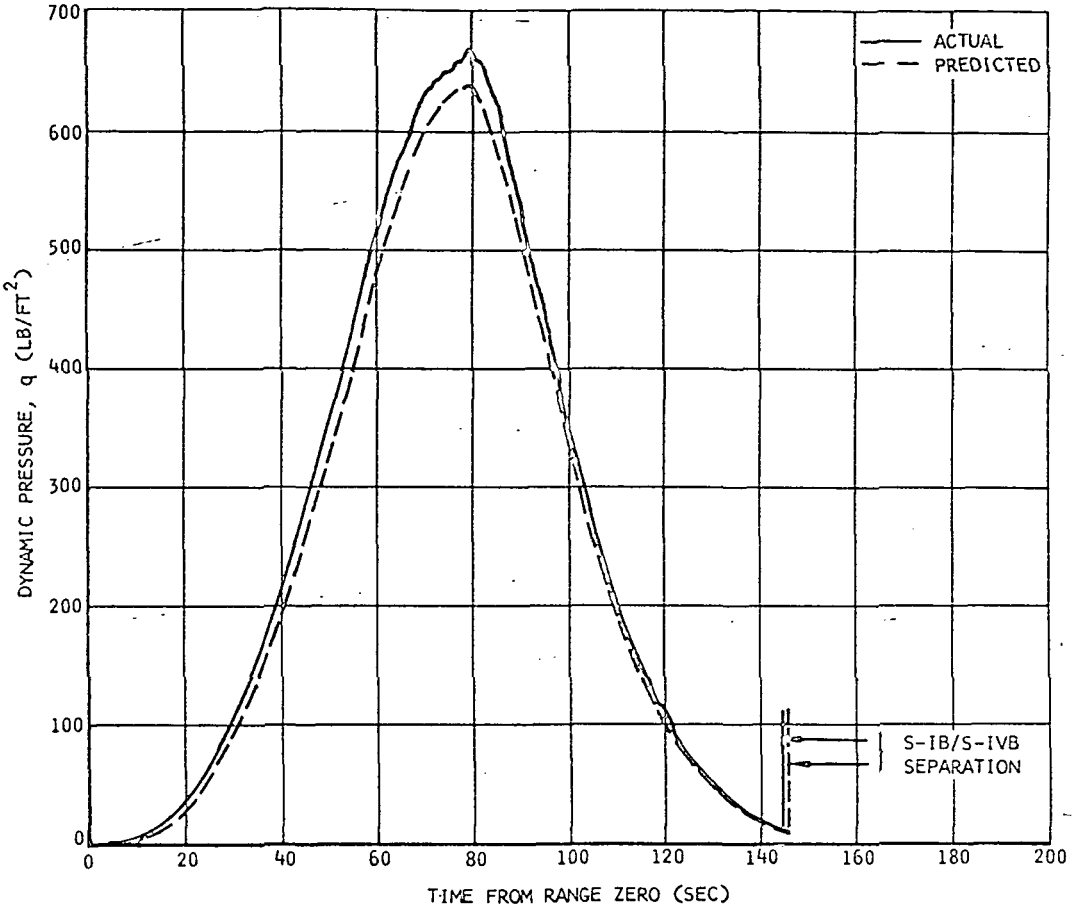


Figure 6-3. S-IB Stage Flight Axial Acceleration History



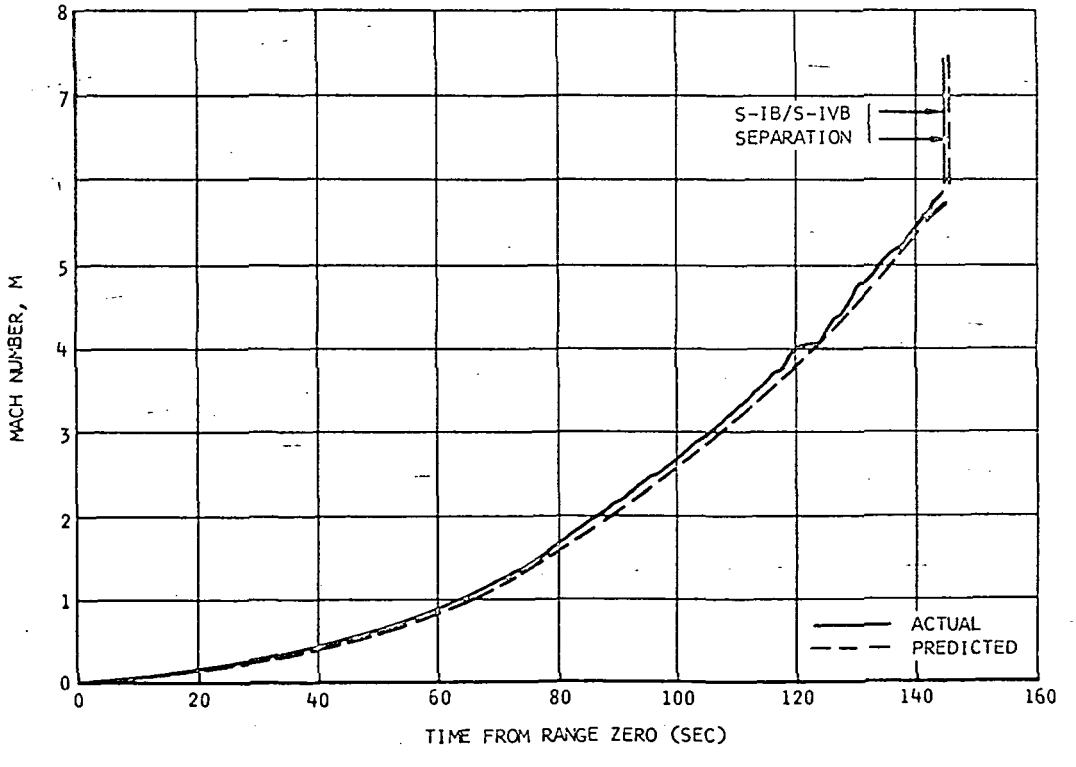


Figure 6-4. Dynamic Pressure and Mach Number Histories

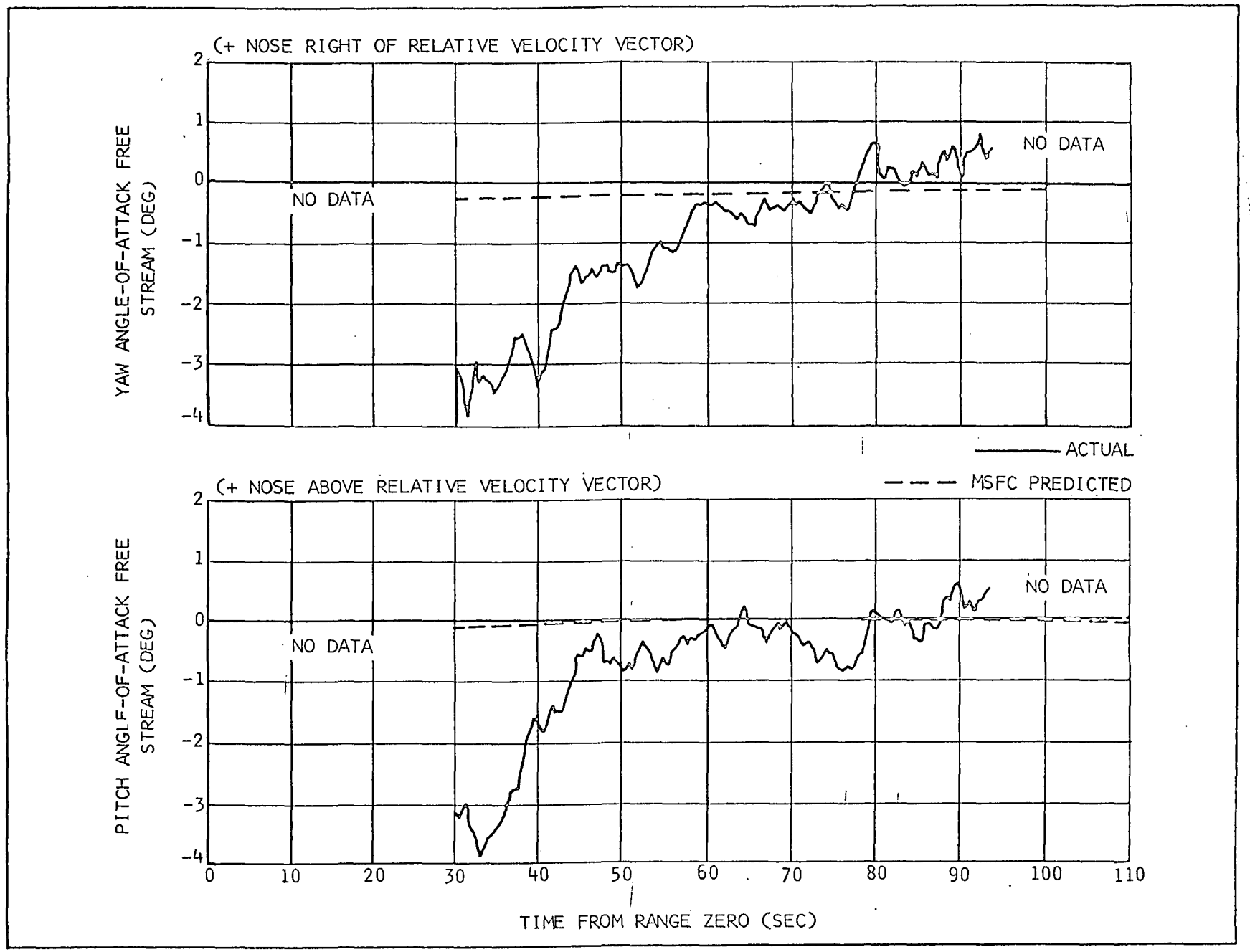


Figure 6-5. Pitch and Yaw Angle of Attack Histories

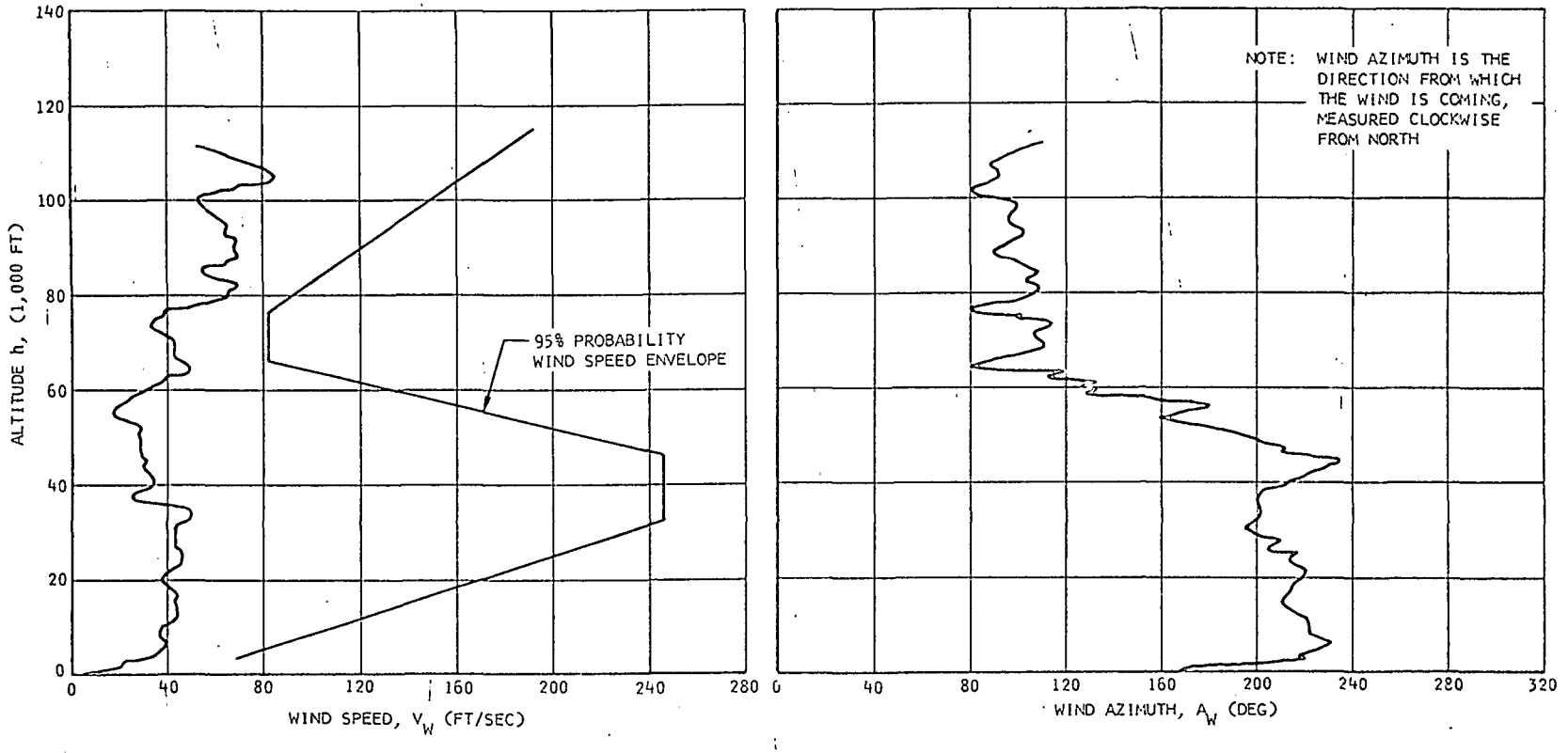


Figure 6-6. Wind Speed and Azimuth Profile

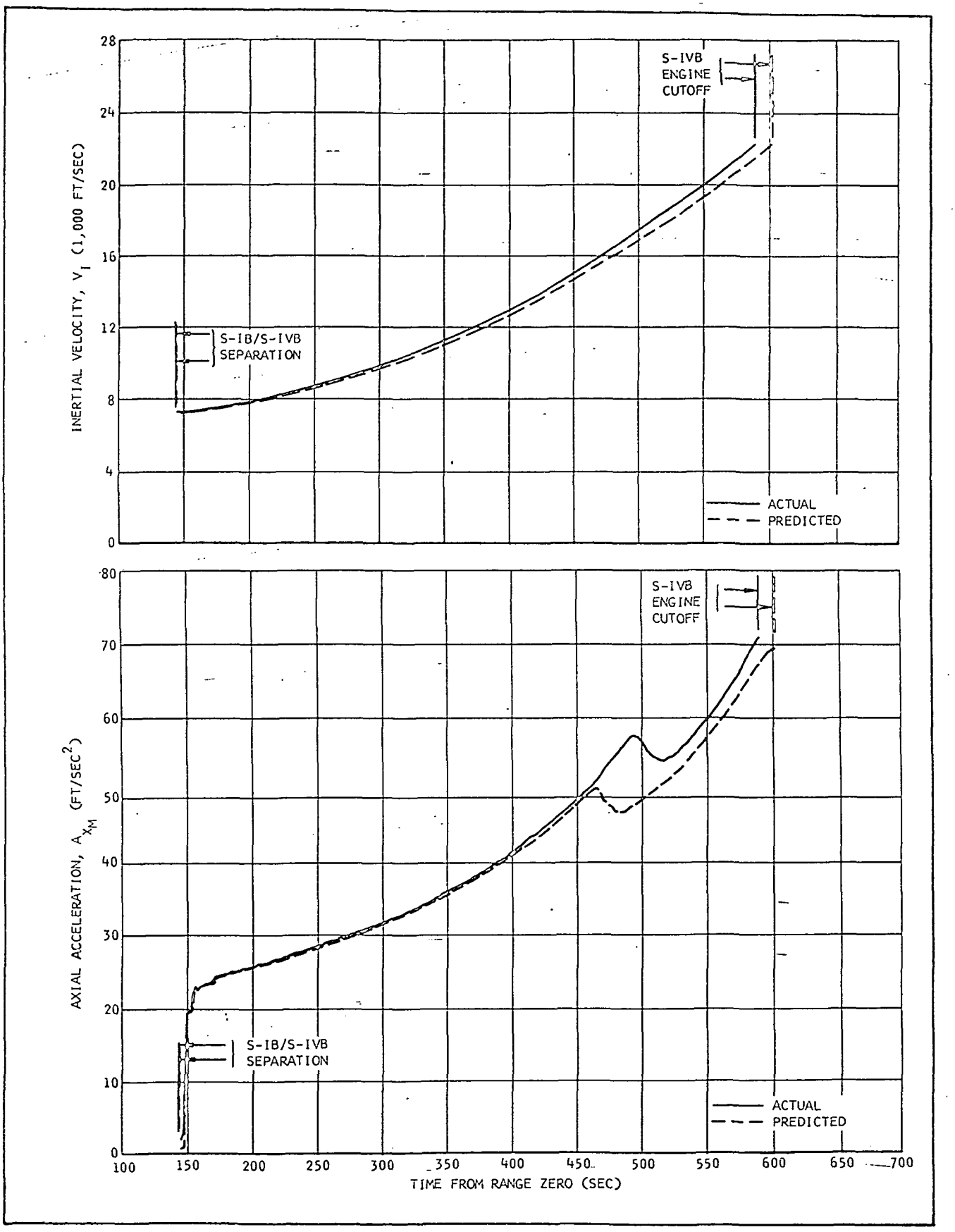


Figure 6-7. S-IVB Stage Flight Inertial Velocity and Axial Acceleration History

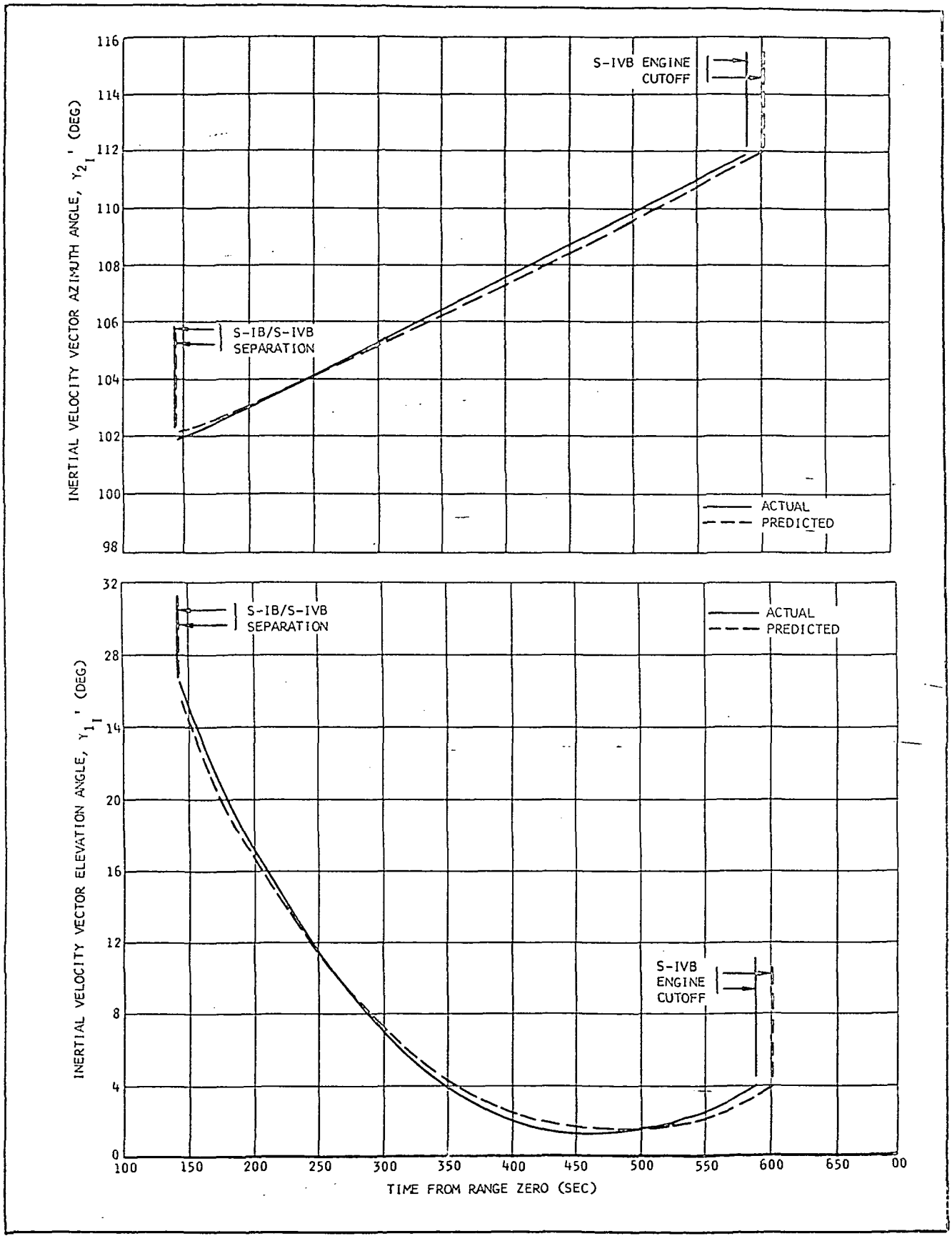


Figure 6-8. S-IVB Stage Inertial Velocity Vector Elevation Angle and Azimuth Angle History

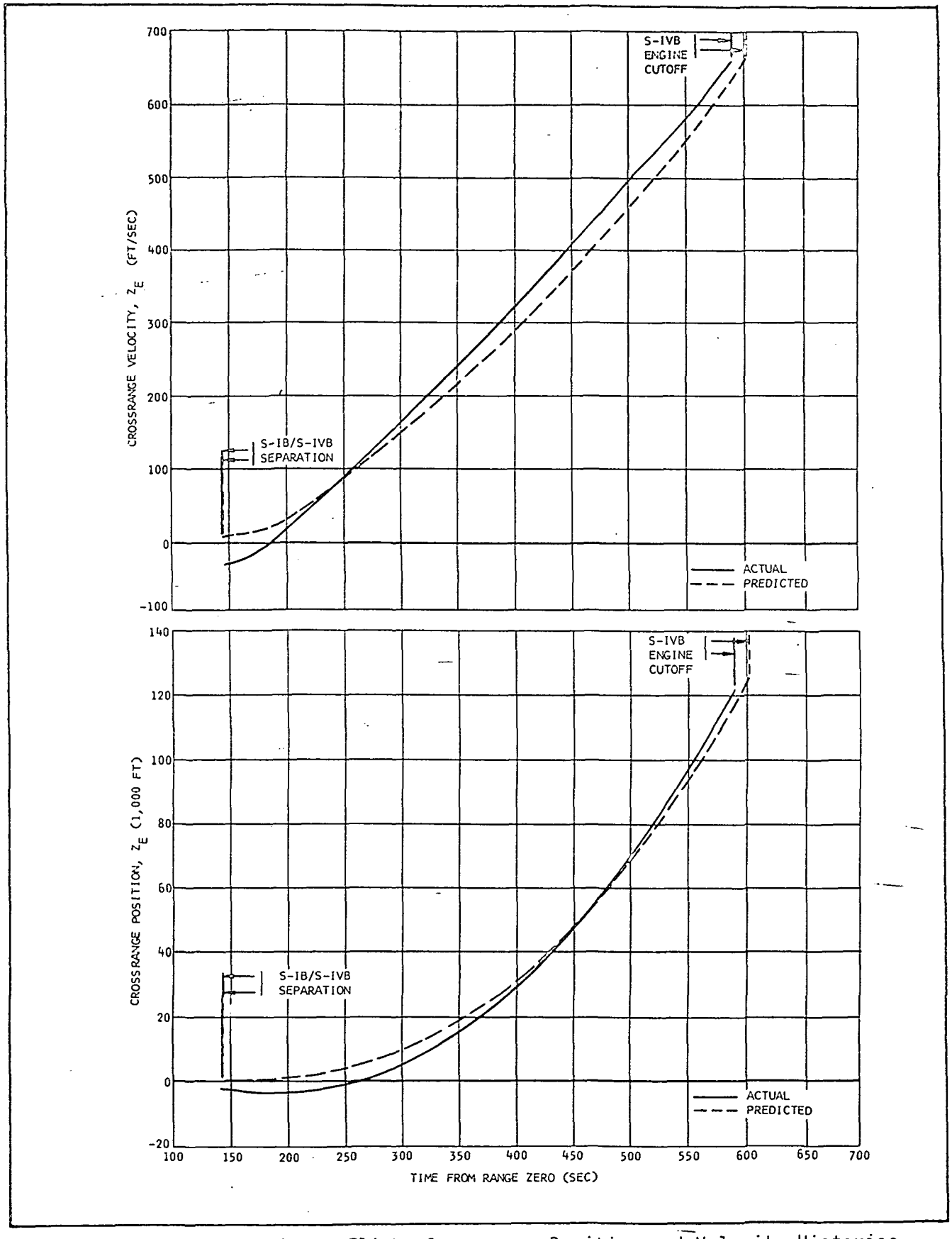


Figure 6-9. S-IVB Stage Flight Crossrange Position and Velocity Histories

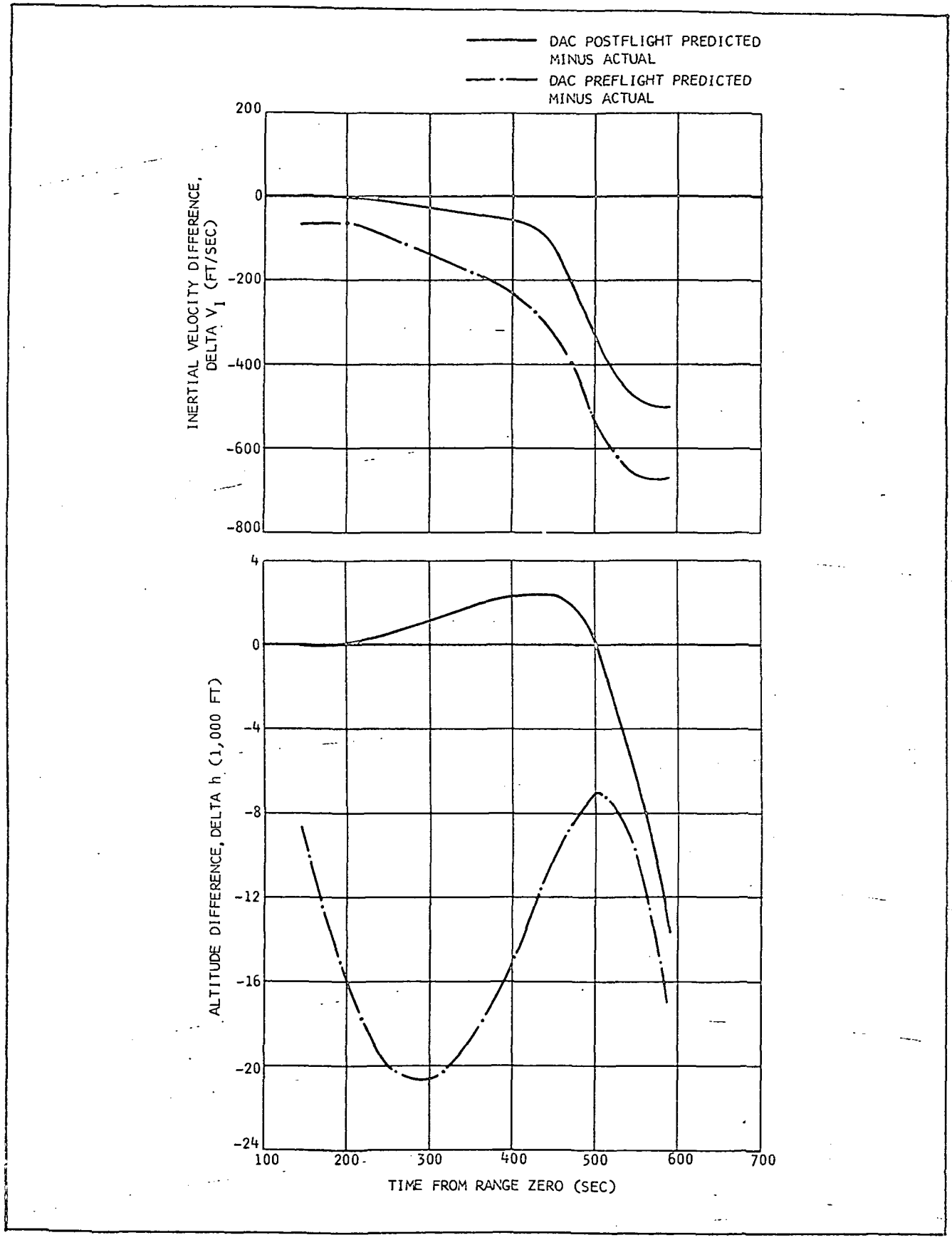


Figure 6-10. Inertial Velocity and Altitude Difference Histories

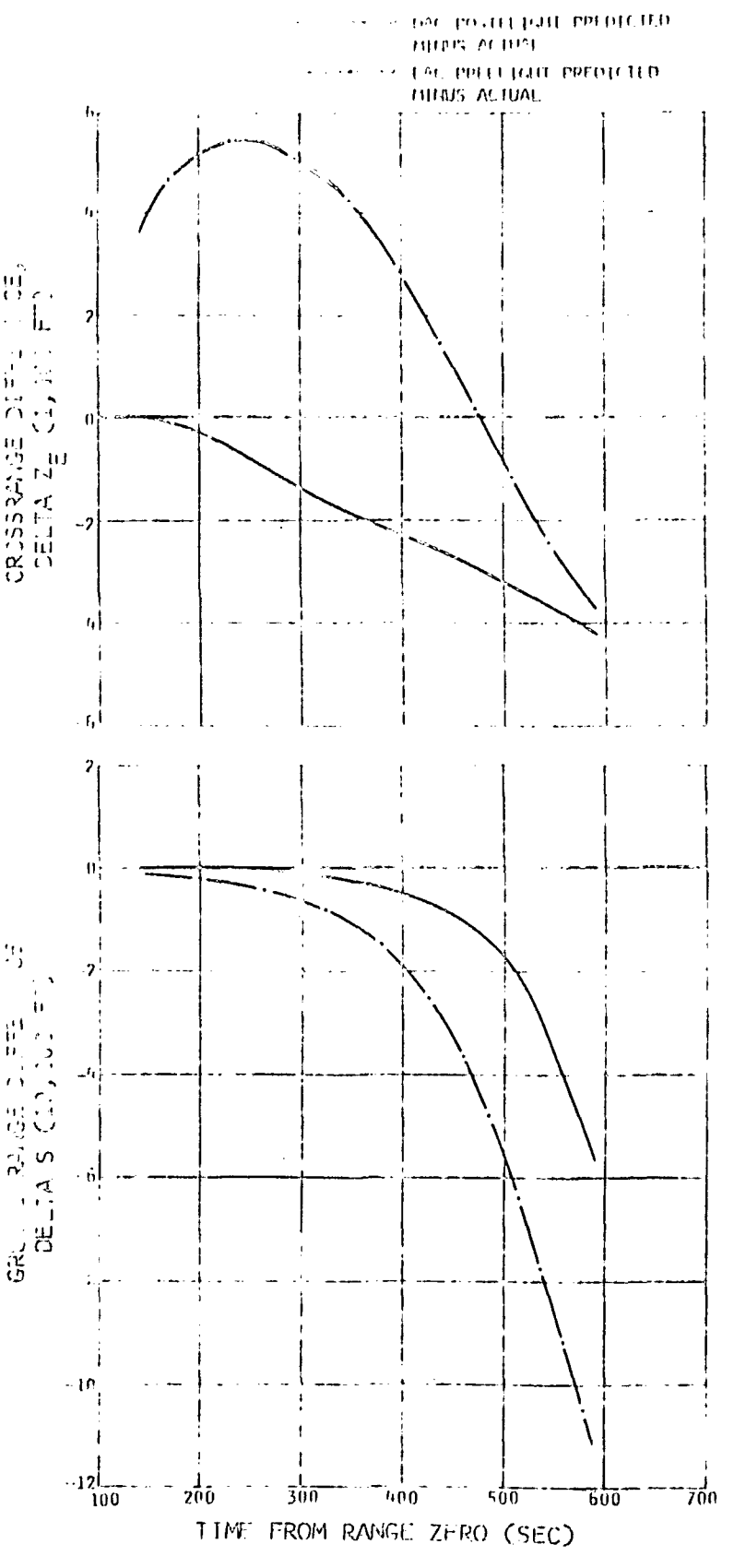


Figure 6-11. Range and Crossrange Difference Histories

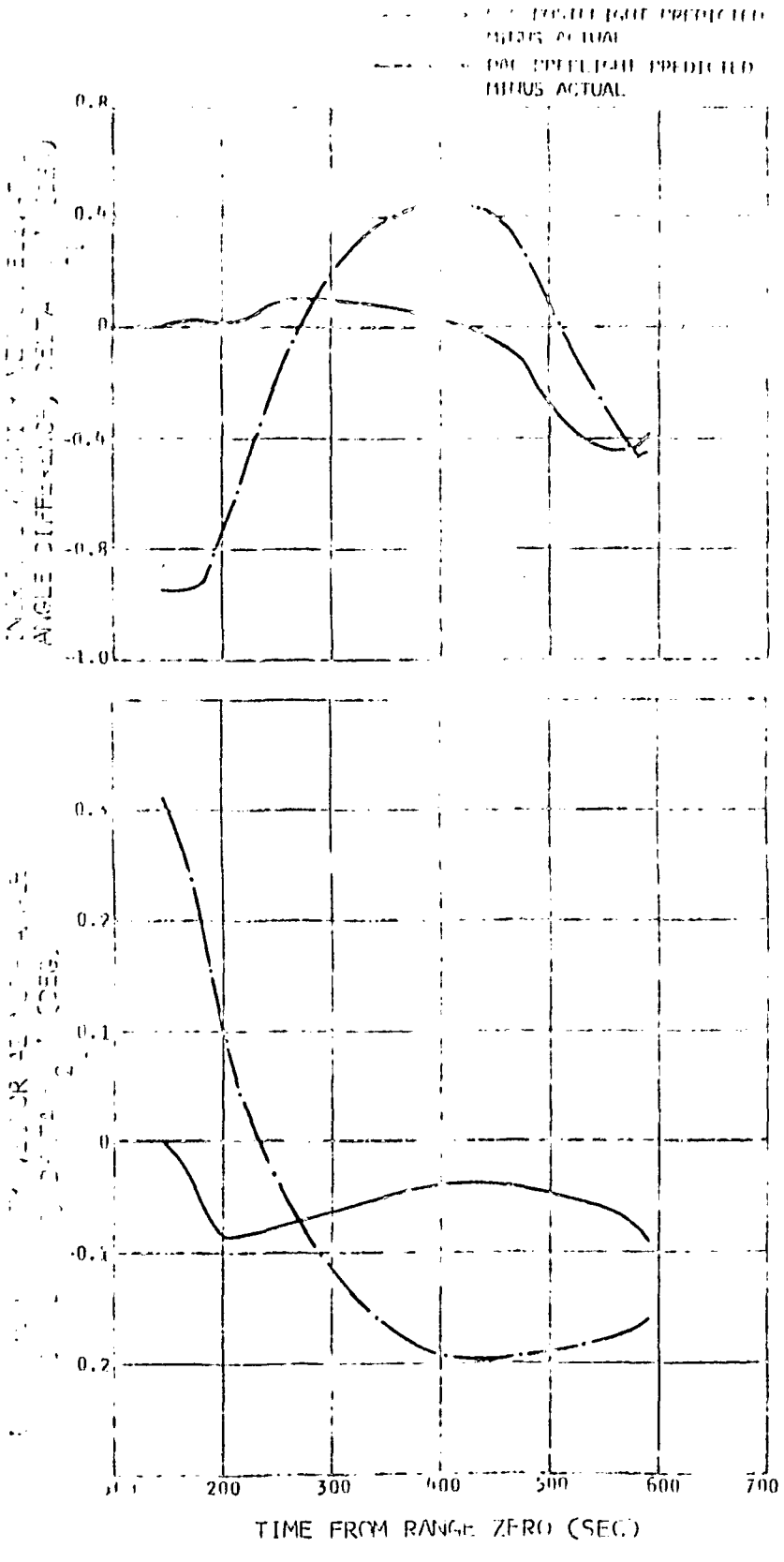


Figure 6-12 Inertial Velocity Vector Elevation Angle and Azimuth Angle Difference

7. MASS CHARACTERISTICS

The S-IVB-202 flight stage mass characteristics presented in this section (table 7-1) are "best estimate" mass characteristics. The best estimate of vehicle mass is computed for S-IVB Engine Start Command and Engine Cutoff Command using the data derived from four analyses: propellant utilization (PU) system, liquid level sensors, engine flow integral, and trajectory reconstruction. Figure 7-1 presents a graphical solution for the best estimate masses. The exact values and accuracies are computed using a simultaneous solution of two equations for the statistically weighted average of masses at Engine Start Command and Engine Cutoff Command. S-IVB stage mass characteristics are presented in figures 7-2 and 7-3 in graphical form and in a more detailed digital form in appendix 1.

7.1 Ice/Frost Formation

The ice/frost formation on the S-IVB stage at liftoff and during flight was estimated using telemetered LH2 tank external skin temperature data and films, both still and cinematic, prior to and during the AS-202 launch.

The ice/frost formation was estimated to be 50 lbm (very light) and was confined to the areas around the main and auxiliary tunnels.

7.2 Adapter Panels

At the time of service propulsion system (SPS) ignition (RO +610 sec), the plume impingement on the command service module adapter panels, hinged at positions III and IV, blew the panels back either to 170 deg from the vehicle centerline, or caused them to be separated from the vehicle entirely. Since the force of the SPS plume impingement was sufficient to break or tear loose the panel restraining cables, it was assumed, for this analysis, that the panels were separated from the vehicle.

The above assumptions are based on video tape and telemetered accelerometer data.

TABLE 7-1
MASS CHARACTERISTICS (lbm)

ITEM	AS-202 LIFT-OFF	S-IB/ S-IVB SEP	S-IVB ESC	S-IVB 90 PCT THRUST	S-IVB PU ACTIVATE	S-IVB EMR CUTBACK	S-IVB ECC	S-IVB ETD	CSM SEP	SPS FIRING DISTRB	LOSS OF SIGNAL
Aft frame	25	0	0	0	0	0	0	0	0	0	0
Detonation pkg	4	0	0	0	0	0	0	0	0	0	0
Frost	50	0	0	0	0	0	0	0	0	0	0
Ullage rkt grn	176	172	109	0	0	0	0	0	0	0	0
Ullage rkt cse	222	222	222	222	222	0	0	0	0	0	0
Launch escape	8,611	8,611	8,611	8,611	8,611	0	0	0	0	0	0
SLA ring	91	91	91	91	91	91	91	91	0	0	0
Command module	12,061	12,061	12,061	12,061	12,061	12,061	12,061	12,061	0	0	0
Service module	9,845	9,845	9,845	9,845	9,845	9,845	9,845	9,845	0	0	0
SM propellant	22,483	22,483	22,483	22,483	22,483	22,483	22,483	22,483	0	0	0
Adapter	3,725	3,725	3,725	3,725	3,725	3,725	3,725	3,725	3,725	2,579	2,580
Instrument unit	4,492	4,492	4,492	4,492	4,492	4,492	4,492	4,492	4,492	4,492	4,492
S-IVB-202 dry stg	23,055	23,055	23,055	23,055	23,055	23,055	23,055	23,055	23,055	23,055	23,055
LOX ullage gas	34	34	34	37	38	285	367	367	343	343	82
LOX in tank	193,109	193,109	193,109	192,568	191,651	46,316	3,648	3,532	3,518	3,504	3,174
LOX in ports	13	13	13	13	13	13	13	13	13	13	13
LOX in lines	246	246	246	246	246	246	246	246	246	246	246
LOX in engine	108	108	108	108	108	108	108	108	108	108	108
LOX below valve	0	0	0	30	30	30	30	0	0	0	0
LH2 ullage gas	189	189	189	191	192	347	470	471	476	484	700
LH2 in tank	37,016	37,016	37,016	36,871	36,671	10,170	1,552	1,527	1,522	1,513	1,298
LH2 in lines	38	38	38	38	38	38	38	38	38	38	38
LH2 in engine	10	10	10	10	10	10	10	10	10	10	10
LH2 below valve	0	0	0	10	10	10	10	0	0	0	0
Cold He quad 1	172	172	172	171	171	115	96	96	96	96	96
Cold He quad 2	172	172	172	171	171	115	96	96	96	96	96
APS prop FP 1	64	64	64	64	63	62	62	61	60	58	44
APS prop FP 3	64	64	64	64	63	61	61	61	60	58	34
APS helium	3	3	3	3	3	3	3	3	3	3	3
Hydraulic oil	15	15	15	15	15	15	15	15	15	15	15
GN2 hyd reserv	2	2	2	2	2	2	2	2	2	2	2
Air hyd pump	1	1	1	1	1	1	1	1	1	1	1
He eng pneu	3	3	3	3	3	3	3	3	3	3	3
He veh pneu	1	1	1	1	1	1	1	1	1	1	1
GH2 start tank	5	5	5	0	1	1	1	1	1	1	1
Env cont fluid	43	43	43	43	43	43	43	43	43	43	43
Total mass	316,147	316,064	316,001	315,242	314,129	133,745	82,625	82,445	37,924	36,761	36,132
Time from range zero	0.933	144.270	145.624	149.126	151.628	475.720	588.473	589.764	596.970	610.200	941.000

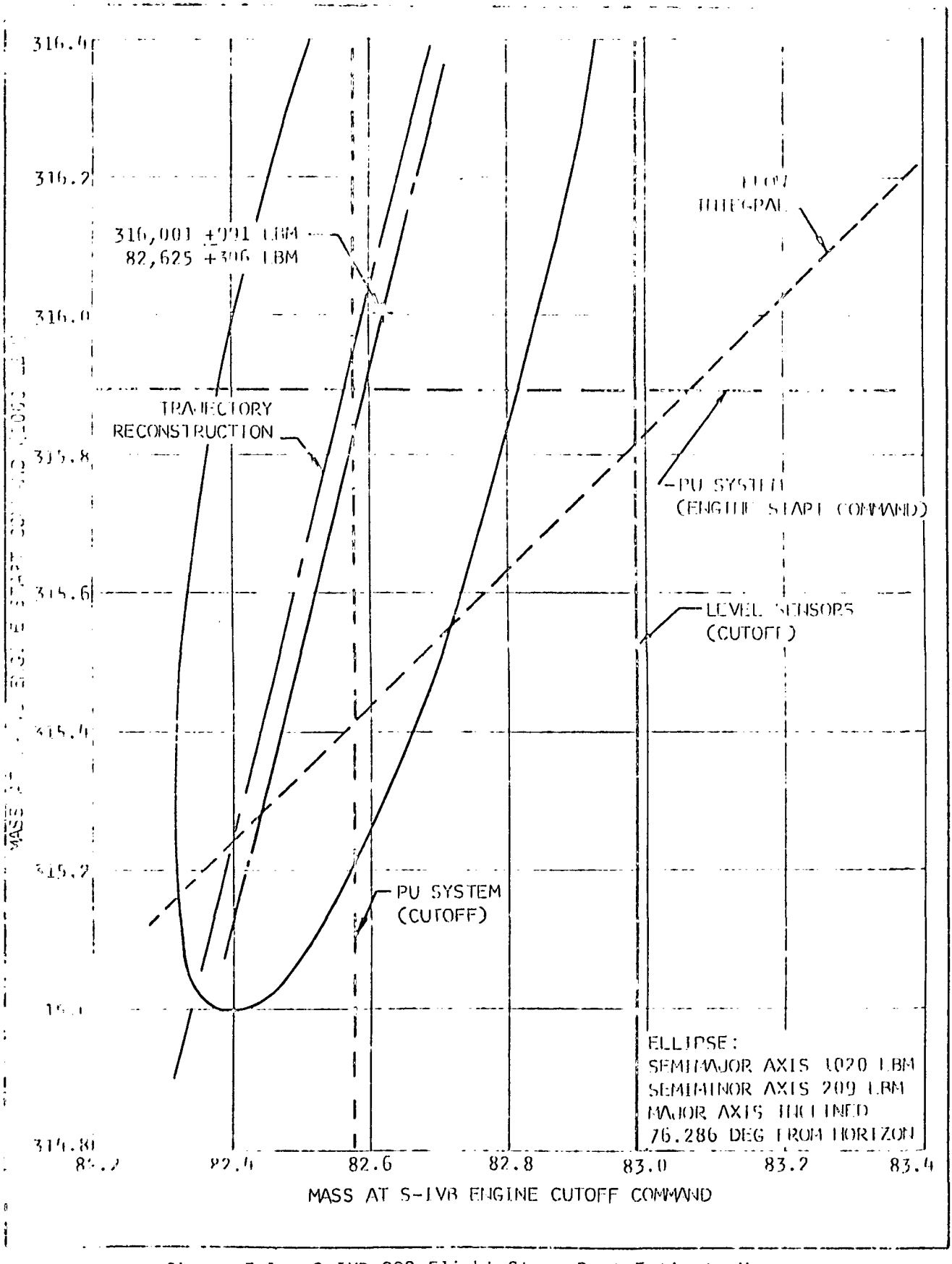


Figure 7-1. S-IVB-202 Flight Stage Best Estimate Mass

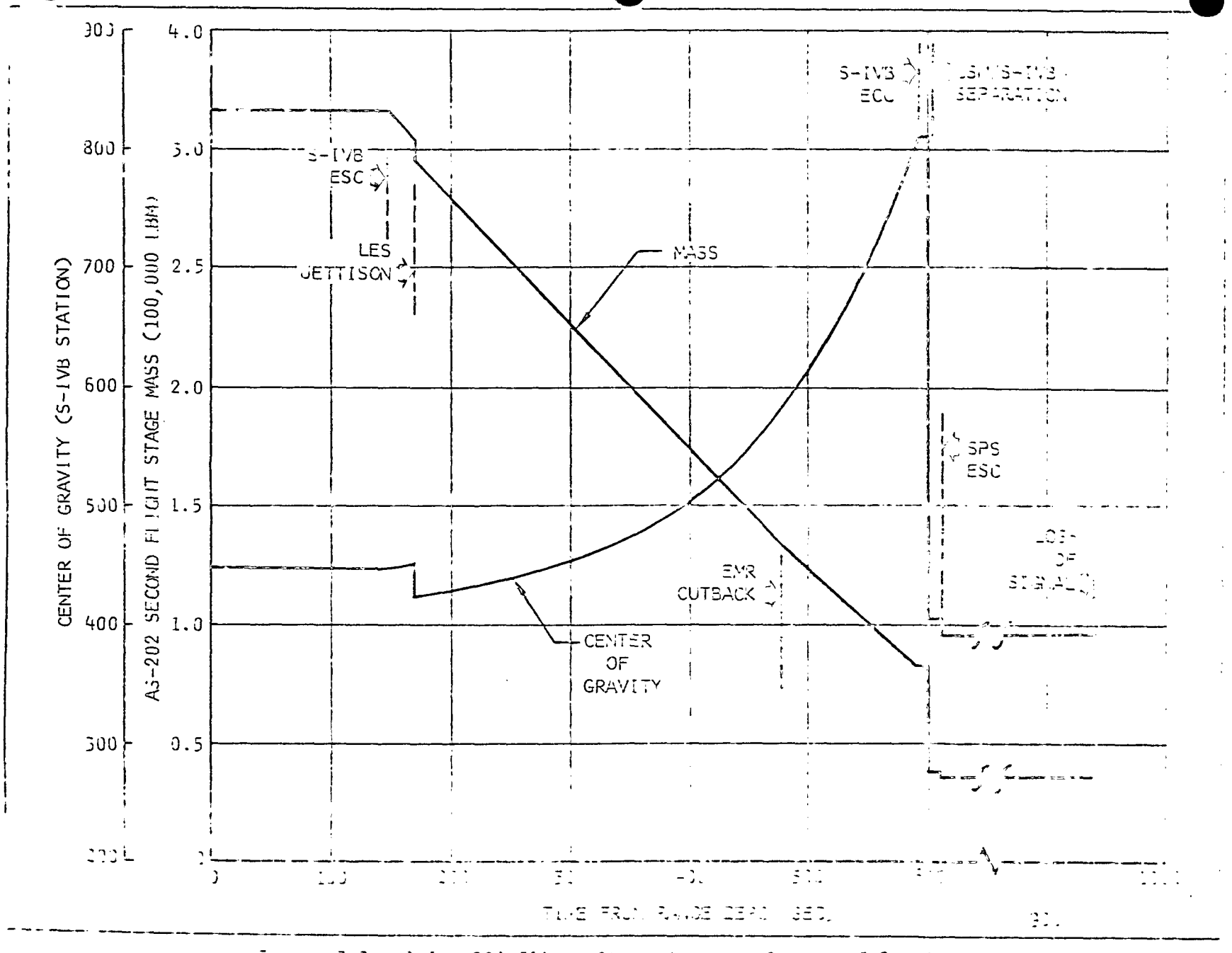


Figure 7-21. AS-202 Flight Stage Mass and Center of Gravity

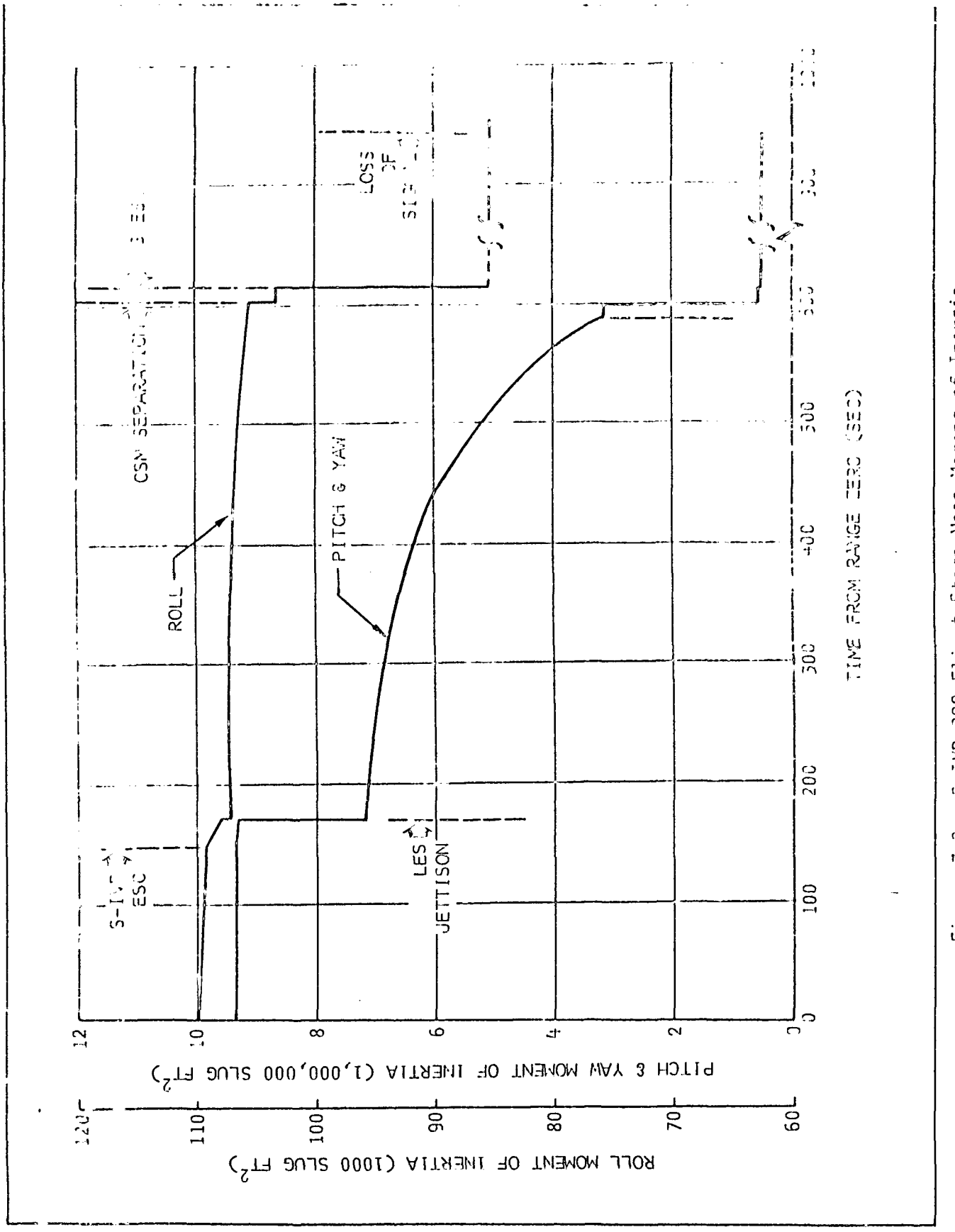


Figure 7-3. S-IVB-202 Flight Stage Mass Moment of Inertia

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8. ENGINE SYSTEM

Rocketdyne engine, S/N J-2016, was mounted on the S-IVB flight stage. This engine (figure 8-1) was delivered to DAC on 13 April 1965 with an accumulated run time of 500.4 sec. Before the flight, an additional 783 sec were accumulated, bringing the total engine time to 1,283 sec. This time resulted from four countdowns that were required for a successful acceptance firing of the stage. Of these firings, CD 61404, the only one terminated because of the engine system, was aborted at ESC +2.7 sec because of an erroneous signal from the combustion stability monitor. Total engine time, as of Engine Cutoff Command of the successful flight, was 1,722 sec.

The following engine modifications were completed after the acceptance firing and prior to the flight:

a. Thermal insulation was added to the main oxidizer valve (MOV) control line for temperature control of the pneumatic actuating gas.

b. The oxidizer turbine bypass valve orifice, used to simulate altitude start conditions, was removed prior to flight.

c. The fast shutdown valve was replaced.

d. A poppet orifice was added to the MOV open control which changed the action time of the MOV from 1,650 ms to 1,390 $\pm$40 ms.

e. An orifice was installed in the gas generator open control system to slow down the gas generator valve opening time.

8.1 Engine Chilldown and Conditioning

The engine chilldown and conditioning were satisfactorily accomplished, allowing the proper conditions for engine start. It has been impossible, however, to evaluate the performance of the GSE in these operations, because the data normally used for this evaluation were not received from Kennedy Space Center. Based on the conditions achieved, the GSE appears to have performed satisfactorily.

8.1.1 Engine Turbopump Chilldown

The engine LOX and LH2 turbopumps were adequately chilled, and the temperatures and pressures were within requirements at Engine Start Command. The LH2 pump performance during start transient was satisfactory (figure 8-2).

8.1.2 Thrust Chamber Chilldown

Thrust chamber chilldown was initiated at T -15 min and terminated at liftoff with a skin temperature of 212 deg R. At Engine Start Command, the thrust chamber temperature (C0199) was 238 deg R (figure 8-3) satisfying the engine start requirement of 260 ±50 deg R. The temperature increase prior to liftoff was an effect of increased demands on the gas heat exchanger.

The profiles of both the thrust chamber skin temperature and the lower manifold tube temperatures (C0385 and C0386) were similar to those for the S-IVB-201 flight. These similar profiles were a result of similar hardware configurations and environmental conditions in the aft interstage during boost.

The lower manifold tube temperature profile during boost on S-IVB-202 stage deviated from that on the S-IVB-203 stage flight. The thrust chamber on S-IVB-203 was insulated, causing instrumentation to reflect thrust chamber conditions rather than environmental conditions. Therefore, S-IVB-203 data, which shows a steady temperature increase throughout boost, is a more valid representation of the return manifold temperature profile.

8.1.3 Engine Start Sphere and Control Sphere Chilldown and Loading

Chilldown and loading of the engine start sphere was adequately completed prior to liftoff, resulting in acceptance conditions at Engine Start Command. The sphere warmup rate was 0.9 deg R/min during boost (figure 8-4). The pressure and temperature at Engine Start Command were 1,269 psia and 286 deg R (requirements are 1,300 ±100 psia and 240 ±50 deg R), giving a mass of 3.26 lbm of GH2. The mass remaining at engine cutoff was 0.75 lbm, indicating a consumption of 2.51 lbm.

The engine control sphere conditioning was adequate to meet the objective of cooling the sphere to the required limits at engine start (2,800 to 3,450 psia and 290 ±30 deg R). At Engine Start Command the sphere pressure was 2,982 psia, the temperature was 284 deg R, and the loaded mass was 1.91 lbm (figure 8-4). Total helium usage was 0.42 lbm.

8.2 J-2 Engine Performance

The engine performance was satisfactory throughout mainstage operation. Plots of selected data used as inputs to the computer programs listed in table 8-I are presented in figures 8-5 through 8-9. The engine propellant inlet conditions are presented in sections 10 and 11. Steady state computed performance parameters are presented in figure 8-10.

The S-IVB-202 stage engine performance was reconstructed from engine start to engine cutoff. The results of three computer program engine performance reconstructions were combined statistically to obtain the final engine performance. The average results of these programs were in agreement within 0.808 percent for thrust, 0.865 percent for total propellant flowrate, 0.258 percent for specific impulse, and 1.707 percent for mixture ratio (table 8-I).

8.2.1 Start Transient

The J-2 engine start transient was satisfactory. The engine performance values are summarized as follows:

	Flight	Stage Acceptance	J-2 Engine Log Book
Time from ESC to 90 percent performance level (sec)	3.502	3.496*	3.42**
Thrust rise time (sec)	2.138	1.999	2.21
Total start transient impulse (lbf-sec)	175,607	177,077	198,000†
Maximum rate of thrust increase (lbf/10 ms)	10,506	8,333	40,000††

* Adjusted +315 ms to compensate for 1.0 sec flight delay time
** Unadjusted for flight delay time
† Based on rated thrust at standard altitude conditions
†† Maximum allowable

Thrust buildup to the 90 percent performance level (thrust chamber pressure = 618 psia) and the thrust rise time were very close to the S-IVB-202 acceptance firing result. Thrust rise time is defined as the time from first indication of thrust buildup to the 90 percent performance level. Figure 8-11 shows the thrust chamber pressure during start transient and the thrust buildup to the 90 percent performance level for S-IVB-202 acceptance and flight as determined by computer program F839. Figure 8-11 also presents a comparison of the S-IVB-202 and 203 flight start transient thrust histories. The maximum and minimum thrust bands shown in figure 8-11 apply to the flight data only due to the additional time delay between acceptance and flight start transient histories.

The deviation of the S-IVB-202 thrust transient from the S-IVB-203 transient from approximately ESC +2.8 to +3.6 sec is attributed to the main LOX valve transient as shown in figure 8-12 and discussed in paragraph 8.4.1.

It was expected that the modifications affecting MOV performance would result in a flight thrust transient faster than that exhibited during the S-IVB-202 acceptance firing. The engine modifications made to S-IVB-202 were similar to those made on the S-IVB-203 flight vehicle but the transient was not improved (figure 8-12 and paragraph 8.4.1). As expected, there was no thrust overshoot during the start transient.

8.2.2 Steady-State Operation

Engine steady-state performance was calculated by use of computer programs AA89, G105-3, and F823-1. These programs used various measurements and predetermined correlations to reconstruct the test, giving performance parameters and their profiles. A description of the operation and comparison of the results of each program is presented in table 8-1. The tabulated results are presented in appendices AP-2 through AP-4 and the average results are compared to predictions in table 8-2.

The following corrections or alterations were performed on the raw data prior to its use in the evaluation programs. These changes were based on acceptance firing data, past experience, and evaluation of the individual parameters.

Measurement	Corrections	Programs Affected
C0134 (LH2 pump discharge temp)	Invalid -- replaced by C0012 (LH2 bleed valve temp)	G105 P823
C0200 (LH2 injection temp)	Invalid after ESC +340 sec, overridden by constructed data	P823
F0002 (LH2 flowrate)	Biased +54.43 gpm (as determined by data pip count)	G105

8.2.2.1 Steady-state Performance

The J-2 engine demonstrated satisfactory performance throughout the steady-state portion of the S-IVB burn.

The performance profiles, as determined by the various computer programs and averaged by program PA49, are shown in figure 8-10. Comparison of the flight performance with that of previous tests on this engine indicated deviations of approximately 2 percent, which is considered satisfactory; although no standard for run-to-run deviations had been established prior to engine S/N J-2020. It is interesting to note the history of the efforts to determine the performance level of this engine. The level established during the Rocketdyne acceptance tests differed from that determined for the DAC acceptance firing because of several hardware changes made after the Rocketdyne tests (DAC Report No. SM-47468, Saturn S-IVB-202 Stage Acceptance Firing Test Report). Therefore; the flight prediction was based on the stage acceptance test performance level. In the interim between the DAC acceptance firing and the flight, a new Rocketdyne engine acceptance evaluation was made available. By the time of the S-IVB-202 flight, there was considerable uncertainty as to the actual performance level of engine J-2016. A review of the flight reconstructions shows that the flight performance level and the DAC stage acceptance firing level are in close agreement. Table 8-3 compares average flight performance parameters with the flight prediction and the acceptance firing. The comparison is made with the PU valve closed and during reference mixture ratio operation. Also included is the overall average performance. The average values for the flight are consistently higher because of the PU valve operation and a slightly higher than predicted engine performance.

The cutback time of the PU valve was predicted to occur at ESC +306 sec. The valve actually cut back 24 sec later at ESC +330 sec. This disparity was within the predicted deviation of ±45 sec. A detailed explanation of the 24-sec valve cutback deviation can be found in section 14. A slight shift in the performance was noted at ESC +300 sec when a fuel pressurization was commanded to the step mode, thus increasing pressurant flowrate (paragraph 11.1.2). This shift was normal and expected.

Engine Cutoff Command occurred at ESC +442.849 sec, when the vehicle velocity reached the desired value. This was 13.05 sec sooner than predicted. Factors contributing to the early cutoff were: extended operation with a closed PU valve resulting in higher than predicted average thrust, and higher than predicted S-IB and S-IVB stage performance (paragraph 8.5). Extrapolation of the steady-state performance indicates that a LOX depletion would have occurred at ESC +452.214 sec or 8.063 sec sooner than predicted. Of this deviation, 1.5 sec is due to the difference in the engine "tag" values used for the prediction and the values observed in the flight. The remainder of the deviation is due to the high rate of LOX consumption caused by the late PU valve cutback.

8.7.2.2 Thrust Variations

Thrust variations after PU valve cutback were primarily induced by PU valve control movements. Valve dynamic response is discussed in detail in section 14. Thrust variations during the period of constant engine mixture ratio (EMR), the period from valve cutback +50 sec to ECC -70 sec, and the period from ECC -70 sec to ECC, are presented in table 14-5. The actual values were within MSFC suggested allowable limits during the period of high EMR. Thrust variations were not applicable for the second time period (after valve cutback) due to the late PU valve cutback. (PU valve cutback +50 sec occurred at ESC +380 sec, and ECC -70 sec occurred at ESC +372 sec, thus eliminating the period altogether.) The limits were exceeded in all three categories during the last 70 sec of flight. The predicted maximum rate of thrust change also exceeded the suggested limits. Late PU valve cutback increased the thrust variations during this period because at ECC -70 sec the valve was still in transient operation. It should be noted that the thrust limits shown in table 14-5 apply to S-IVB-204 and are

presented for reference purposes only. Nominal cutback time will be changed from the present ESC +306 sec to ESC +280 sec starting with S-IVB-206 to alleviate this situation.

8.2.3 Cutoff Transient

The time lapse between Engine Cutoff Command, as received at the J-2 engine, and thrust decay to 11,250 lbf was 748 ms compared to 781 ms for the acceptance firing. Both values were within the maximum allowable duration of 800 ms. The cutoff impulse to 11,250 lbf was calculated to be 47,544 lbf-sec as compared to 48,061 lbf-sec for the acceptance firing. This cutoff impulse value to 11,250 lbf is not in agreement with the engine data log (36,280 lbf-sec based on rated thrust and standard altitude conditions) and the Rocketdyne J-2 engine manual No. R-3825-1 (34,918 $\pm$8,185 lbf-sec). The deviation from Rocketdyne nominal values, which are based on thrust load cell data, is caused by a time lag in the chamber pressure measurement from which computer program F839 calculates cutoff impulse. The time lag, which results from the finite time required to vent the chamber pressure transducer during cutoff transient, has averaged about 40 ms on previous acceptance tests and is under investigation by the engine manufacturer. The actual cutoff impulse was thus less than that calculated by F839. The time lapse from Engine Cutoff Command to zero thrust was 1.677 sec and the total cutoff impulse accumulated was 51,423 lbf-sec. Figure 8-13 presents the combustion chamber pressure data for the cutoff transient and the cutoff transient thrust to zero thrust for acceptance and flight as computed by program F839. Figure 8-14 presents accumulated cutoff impulse from Engine Cutoff Command to zero thrust. Based on a total inertial velocity gain of 20.3 ft/sec, obtained from guidance data, the total cutoff impulse was determined to be 52,160 lbf-sec. This value was measured from guidance cutoff time to end of thrust decay, and compares favorably with that obtained from engine analysis. The change in cutoff velocity due to cutoff impulse as computed from engine analysis and acceptance test is 20.05 ft/sec and 23.62 ft/sec respectively.

8.3 Sequence of Events

The engine sequencing was satisfactory throughout flight and was compatible with engine logic and flight test plan. Table 8-4 shows the times of significant flight events as compared to the nominal times. Figure 8-15 shows the engine power rise as controlled by the sequence of events. Some flight events are difficult to obtain because of the reduced data sampling rate available during flights. These times have been calculated based on acceptance data and, therefore, may not be of the highest accuracy. The fuel lead time, as usual, was extended for flight operation. For this flight, it was 1.009 sec compared to 0.640 sec on the acceptance firing. The PU system was activated at ESC +6.4 sec beginning the program mixture ratio operation. The main LOX valve appeared to open slowly. The hardware changes, made to speed the opening of the main LOX valve, caused some deviation between the flight and the acceptance firing sequence of events. The lower rate of data acquisition during flight reduced the ability to define the flight valve travel history.

8.4 Component Operation

8.4.1 Main LOX Valve

The main LOX valve performance was slower than anticipated, although not unsatisfactory, during the engine start sequence. The main LOX valve first stage travel and plateau times during the valve opening were considered satisfactory compared to the Rocketdyne nominal values for a dry valve at 70 deg F, as shown below:

Section	Engine Manufacturer Nominal Time (ms)	Observed Time (ms)	Deviation From Nominal (ms)
First stage travel	50 ±25	180	+130
Plateau	365 ±120	650	+175
Second stage travel	1390 ±40	2320	+930
Total	1805 ±185	3040	+1235

The second stage travel time exceeded the Rocketdyne nominal time by 930 ms. The main LOX valve total opening profile was similar to that during the acceptance firing (figure 8-12), where the second stage travel time exceeded the Rocketdyne nominal by 1,010 ms. In both cases, the LOX pump discharge pressure buildup preceded the initiation of the second stage valve travel. This pressure rise thereby provided sufficient back pressure to delay the second stage valve movement a similar amount in each case. Prior to flight, an orifice had been installed in the gas generator open control system in accordance with Engineering Change Proposal (ECP) 455. This modification was intended to delay the gas generator opening sufficiently to permit the main LOX valve to lead the LOX pump discharge pressure rise.

A close inspection of the acceptance firing and flight profiles indicates that the flight plateau and second stage travel times were somewhat briefer than the respective times observed during the S-IVB-202 acceptance firing.

It was expected that the installation of the ECP-455 orifice would result in a continuous second stage open position slope, and plateau and second stage travel times of approximately 400 ms and 2,000 ms respectively, as experienced during the S-IVB-203 flight (figure 8-12).

As indicated, the plateau and second stage travel times were somewhat improved. However, the installation of the ECP orifice did not eliminate the severe time lag within the second stage opening position trace.

Insulation material was added to the main LOX valve pneumatic supply line, similar to the S-IVB-203 flight stage. The following table compares temperatures observed on the S-IVB-203 and 202 flight stages at Engine Start Command:

	S-IVB-203 Flight	S-IVB-202 Flight
Main LOX valve skin temperature (°R)	338	350
Main LOX valve control gas line temperature (°R)	445	416

It is apparent from these data that the lower control gas temperature on the S-IVB-202 stage could have been responsible in some degree for the delayed main LOX valve opening because of the additional time required to flow the necessary mass of control gas through the fixed main LOX valve orifice.

The slow valve opening time is presently under investigation by both DAC and Rocketdyne. The valve performance observed on the S-IVB-202 flight, although slower than specification, was not detrimental to stage performance. The main LOX valve closure time was observed to be 313 ms and was considered to be satisfactory.

8.4.2 LH2 Pump

The LH2 pump inlet and outlet pressure and temperature histories were in close agreement with the predicted profiles. LH2 pump discharge pressure responded to the normal stage pressurization system fluctuations, and the LH2 pump speed agreement within 100 rpm of the predicted time history.

8.4.3 LOX Pump

The LOX pump inlet and outlet pressure histories were in close agreement with the predicted values. The LOX pump speed agreed within 50 rpm of the predicted value.

The pump speed, pressures, and temperatures responded as predicted to the PU system cutback.

8.4.4 Turbines

The performance of both the LOX and LH2 turbines was satisfactory. No temperature spikes of LH2 turbine inlet temperature occurred during engine start or cutoff. The LH2 and LOX turbine pressures and temperatures responded as expected during the PU valve cutback.

8.4.5 PU Valve

During the high EMR portion of the flight, the PU valve discharge pressure reflected the stage LOX system pressure fluctuations. The PU valve cutback occurred at ESC +330 sec when the required LOX weight error was

reached. This was within the ±45 sec three-sigma variation from the nominal value of ESC +306 sec. PU system dynamic response is discussed in section 14.

8.4.6 Gas Generator

The performance of the gas generator was satisfactory, as demonstrated by gas generator chamber pressure, injector pressure, and propellant flowrates (figure 8-16). During start, the gas generator valve opened within 220 ms which was 70 ms slower than during the S-IVB-202 acceptance firing because of the installation of ECP-455 orifice (paragraph 8.4.1).

8.5 Flight Simulation Analysis

Using a five-degree-of-freedom trajectory simulation program, propulsion system parameter histories were adjusted so that a S-IVB trajectory could be generated to closely match the observed trajectory (appendix 5, Observed Trajectory). The simulation program employed a differential correction technique which determined the necessary adjustments to thrust and weight flow from the engine analysis, and pitch and yaw engine thrust misalignment angles from the control system analysis to minimize the differences between the simulated and the observed trajectory. Differences between the observed and simulated trajectory are presented in figure 8-17. The estimated accuracies of the observed trajectory and the average deviation between the simulated trajectory are as follows:

Parameter	Observed Trajectory Standard Deviation	Root-Sum-Square of Observed Minus Simulated Trajectory Deviation
Slant range distance (ft)	900	92.1
Altitude (ft)	900	51.3
Earth-fixed velocity (ft/sec)	3	1.35
Earth-fixed velocity azimuth angle (deg)	0.01	0.010

Maximum deviations between the observed and the simulated trajectory were 171 ft in slant range distance, 196 ft in altitude, 3.09 ft/sec in velocity,

and 0.021 deg in earth-fixed velocity azimuth. These deviations are small, being within the accuracy band of the observed trajectory. This indicates that the shapes of the propulsion parameters were accurately determined by the engine analysis. However, to obtain a match of the observed trajectory it was necessary to raise the engine analysis thrust and weight flow 0.19 and 0.26 percent, respectively, which lowered the specific impulse 0.07 percent. Histories of the predicted and simulated thrust, weight flow, and specific impulse are presented in figure 8-18. The average value for these parameters are as follows:

Parameter	Predicted	Simulated
90 Percent Thrust to Engine Cutoff Command		
Average thrust (lbf)	212,012	216,830
Average weight flow (lbm/sec)	498.0	509.7
Average specific impulse (sec)	425.7	425.6
90 Percent Thrust to PU Valve Cutback		
Average thrust (lbf)	223,434	224,890
Average weight flow (lbm/sec)	526.5	529.9
Average specific impulse (sec)	424.4	424.4
PU Valve Cutback Plus 50 Sec to Engine Cutoff Command		
Average thrust (lbf)	183,353	182,670
Average weight flow (lbm/sec)	426.3	424.0
Average specific impulse (sec)	430.1	430.8

The maximum inaccuracies in the simulated propulsion parameters due to the observed trajectory and simulation uncertainties are estimated to be 0.2 percent for thrust and weight flow and 0.3 percent for specific impulse. An additional inaccuracy is added by the uncertainty in the ignition and cutoff weight. As a result, the total inaccuracy in thrust, weight flow, and specific impulse is 0.3 percent in each.

Engine misalignment angles determined from trajectory simulation and control system analysis are in close agreement. The control system analysis established a thrust misalignment angle of 0.25 deg in pitch, producing a nose down attitude error, and an angle of -0.53 deg in yaw, producing a nose right attitude error. The differential correction technique determined that the pitch misalignment angle was 0.27 deg, and the yaw misalignment angle was -0.51 deg. The yaw misalignment angle does not reflect the actual misalignment during flight, but includes the effect of a bias in the servo valve command current (paragraph 19.1). An S-IVB stage ignition weight of 316,005 lbm and cutoff weight of 82,591 lbm were derived from the composite best estimate ignition and cutoff weight (section 7). The weights were derived by finding the point on the flight simulation solution line (figure 7-1) which most closely corresponds to the composite best estimate point.

The flight simulation analysis verified that engine analysis values were in close agreement with the observed trajectory. Average values agreed within 0.26 percent.

The trajectory simulation verifies the 13.05 sec differences between predicted and actual guidance cutoff times. The total components of the short burntime were determined to be as follows: high S-IB stage performance (2.5 sec), high S-IVB stage performance (4.7 sec), and late PU valve cutback (5.5 sec). The total of these components is in close agreement with the difference observed.

TABLE 8-1
COMPARISON OF COMPUTER PROGRAM RESULTS

PROGRAM	INPUT	METHOD	AVERAGE RESULTS
AA89	LOX and LH2 pump inlet pressures and temperatures, PU valve position, and engine tag values	Influence equations relate nominal inlet conditions to nominal performance. Using actual inlet conditions, PU valve position and engine tag values, the actual performance is simulated.	F = 215,290 lbf $\dot{W}_T$ = 505.7 lbm/sec I_{sp} = 425.9 sec EMR = 5.402
G105 Mode 3	LOX and LH2 flowmeters, pump discharge pressures and temperatures, chamber pressures, chamber thrust area	Flowrates are computed from flowmeter data and propellant densities. The C_F is determined from equation $C_F = f(P_c, EMR)$ and thrust is calculated from equation $F = C_F A_t P_c$.	F = 216,892 lbf $\dot{W}_T$ = 510.1 lbm/sec I_{sp} = 425.4 sec EMR = 5.438
F823	Thrust chamber pressure, gas generator pressure, fuel injection temperature, fuel pump discharge temperature, turbine inlet temperature	Total flows of the thrust chamber and gas generator are calculated as a function of respective chamber pressures. Mixture ratio of the chamber is calculated as a function of temperature rise of the fuel in the cooling jacket, and mixture ratio of the GG is calculated as a function of turbine inlet temperature. Thrust is calculated from the equation $F = C_F A_t P_c$.	F = 217,040 lbf $\dot{W}_T$ = 509.2 lbm/sec I_{sp} = 426.5 sec EMR = 5.495
F839	Thrust chamber pressure, chamber throat area	The C_F is computed from equation $C_F = f(P_c)$ and thrust is computed from equation $F = C_F A_t P_c$. The impulse is determined from integrated thrust.	Refer to paragraphs 8.2.1 and 8.2.3.

TABLE 8-2
PREDICTED PROPULSION SYSTEM PERFORMANCE PARAMETERS VS ACTUAL VALUES

PARAMETER	UNIT	PREDICTED VALUE	PREDICTED 3σ DISPERSION	ACTUAL VALUE	DEVIATION
Average stage longitudinal thrust*	lbf	212,012	±5,500	216,407	+4,395
Before PU valve cutback	lbf	223,434	±5,250	224,451	+1,017
After PU valve cutback	lbf	183,353	±16,000	182,316	-1,037
Average LOX flowrate*	lbm/sec	419.558	±18.2	425.58	+6.0
Before PU valve cutback	lbm/sec	446.112	±10.7	448.42	+2.3
After PU valve cutback	lbm/sec	352.639	±33.3	349.96	-2.8
Average LH2 flowrate*	lbm/sec	78.451	±3.2	78.75	+0.3
Before PU valve cutback	lbm/sec	80.406	±2.6	80.10	-0.3
After PU valve cutback	lbm/sec	73.703	±3.9	72.92	-0.8
Average stage mass flowrate*	lbm/sec	498.009	±18.5	508.3	+10.3
Before PU valve cutback	lbm/sec	526.518	±11.0	528.5	+2.0
After PU valve cutback	lbm/sec	426.342	±33.5	422.9	-3.4
Average stage longitudinal specific impulse*	sec	425.72	±3.4	425.9	+0.2
Before PU valve cutback	sec	424.36	±2.8	424.7	+0.3
After PU valve cutback	sec	430.06	±3.6	431.1	+1.0
Engine total impulse to depletion	lb/sec	9.695×10^7	$\pm 14 \times 10^7$	9.697×10^7	$+2.0 \times 10^4$
PU valve cutback time from Engine Start Command	sec	306	±45	330	+24
Time from 90% thrust to engine cutoff (depletion)	sec	457.277	±20	449.727	-8
Total depletion burntime (Engine start to depletion)	sec	460.277	±20	452.214	-8
Effective burntime (90% thrust to Guidance Cutoff Command)	sec	452.34	±16	439.341	-13
Loaded propellants** (LOX)	lbm	193,273	±2,165	193,376	+103
(LH2)	lbm	37,121	±416	36,619	-502
(Total)	lbm	230,394	±2,580	229,995	-399

* Averaged or determined for time period of 90% thrust buildup to Guidance Cutoff Command (GCC). Does not include ullage rocket operation.

** Actual values based on flow integral.

TABLE 8-3
PERFORMANCE COMPARISON

	PU VALVE CLOSED			REFERENCE MIXTURE RATIO			OVERALL AVERAGE		
	ACCEPT.	PREDICTED	FLIGHT	ACCEPT.	PREDICTED	FLIGHT	ACCEPT.	PREDICTED	FLIGHT
Thrust (F) (lbf)	223,800	223,434	224,451	182,000	183,353	182,316	206,400	212,012	216,407
Total mass flowrate ($\dot{W}_T$) (lbm/sec)	526.96	526.5	528.53	421.69	426.3	422.88	481.72	501.48	508.33
Specific impulse (I_{sp}) (sec)	424.7	424.36	424.67	431.6	430.06	431.13	428.5	425.72	425.9
Engine mixture ratio (EMR)	5.495	5.549	5.598	4.649	4.784	4.800	5.114	5.345	5.445
Total impulse (I_t) (lbf/sec)	N/A	N/A	N/A	N/A	N/A	N/A	95.55×10^6	95.9×10^6	95.08×10^6

TABLE 8-4 (Sheet 1 of 5)
ENGINE SEQUENCE S-IVB-202 FLIGHT

Control Events		Contingent Events			Actual Time (ms)	
Meas. No.	Event and Comment	Meas. No.	Event and Comment	Nominal Time from Specified Reference	From ESC	From Spec. Ref.
K0021	*Engine Start Command P/U			0		
		K0007	Helium Control Solenoid Enrg P/U	Within 10 ms of K0021	0 0	0 0
		K0010	Thrust Chamber Spark on P/U	Within 10 ms of K0021	12	12
		K0011	Gas Generator Spark on P/U	Within 10 ms of K0021	12	12
		K0006	Ignition Phase Control Solenoid Enrg P/U	Within 20 ms of K0021	12	12
		K0012	Engine Ready D/O	Within 20 ms of K0006	15	3
		K0126	LOX Bleed Valve Closed P/U	Within 130 ms of K0007	75	75
		K0127	LH2 Bleed Valve Closed P/U	Within 130 ms of K0007	60	60
		K0020	ASI LOX Valve Open P/U	Within 20 ms of K0006	30	18
		K0119	Main Fuel Valve Closed D/O	60 ±30 ms from K0006	68	56
		K0118	Main Fuel Valve Open P/U	80 ±50 ms from K0119	140	72
K0008	**Ignition Detected			Within 250 ms of K0021 P/U	243	243
K0021	***Engine Start Command D/O			Within 1,000 ms from K0021 P/U	500	500

* Engine ready and stage separation signals (or simulation) are required before this command will be executed. This command also actuates a 640 ±30 ms timer which controls energizing of the start tank discharge solenoid N010 (K0096)

** This signal must be received within 1,110 ±60 ms of K0021 P/U or cutoff will be initiated.

*** This signal drops out after a time sufficient to lock in the engine electrical system.

TABLE 8-4 (Sheet 2 of 3)
ENGINE SEQUENCE S-IVB-202 FLIGHT

Control Events		Contingent Events			Actual Time ms	
Meas. No.	Event and Comment	Meas. No.	Event and Comment	Nominal Time from Specified Reference	From ESC	From Spec. Ref.
K0096	*Start Tank Disc Control Solenoid Enrg			1,000 ±30 ms from K0021	1,009	1,009
		K0123	Start Tank Disc Valve Closed D/O	100 ±20 ms from K0096	1,104	95
		K0122	Start Tank Disc Valve Open P/U	100 ±20 ms from K0123	1,234	130
K0005	Mainstage Control Solenoid Enrg			450 ±30 ms from K0096	1,433	424
		K0096	Start Tank Disc Control Solenoid Enrg D/O	450 ±30 ms from K0096	1,433	424
		K0121	Main LOX Valve Closed D/O	60 ±20 ms from K0005	1,444	424
		K0116	Gas Generator Valve Closed D/O	85 ±25 ms from K0005	1,474	41
		K0122	Start Tank Disc Valve Open D/O	95 ±20 ms from K0096	1,565	132
		K0117	Gas Generator Valve Open P/U	30 ±15 ms from K0116	1,694	220
		K0124	LOX Turbine Bypass Valve Open D/O	Within 100 ms of K0005	1,731	298
			LOX Turbine Bypass Valve 80% Closed	400 $^{+150}_{-50}$ ms from K0005	1,894	461

* This command is executed upon expiration of a 1 sec delay timer during flight and also actuates a 450 ±30 ms timer which controls the start of mainstage.

TABLE 8-4 (Sheet 3 of 5)
ENGINE SEQUENCE S-IVB-202 FLIGHT

Control Events		Contingent Events			Actual Time (ms)	
Meas. No.	Event and Comment	Meas. No.	Event and Comment	Nominal Time from Specified Reference	From ESC	From Spec. Ref.
		K0123	Start Tank Disc Valve Closed P/U	250 ±40 ms from K0122	1,744	179
		K0125	LOX Turbine Bypass Valve Closed P/U	*	1,994	561
K0158	Mainstage Press. Switch #1 Depress. D/O				2,759	2,759
K0159	Mainstage Press. Switch #2 Depress. D/O				2,784	2,784
K0191	**Mainstage OK					
		K0120	Main LOX Valve Open P/U	2,125 ±150 ms from K0005	4,254	2,821
		K0010	Thrust Chamber Spark on D/O	3,300 ±200 ms from K0005 P/U	4,734	3,301
		K0011	Gas Generator Spark on D/O	3,300 ±200 ms from K0005 P/U	4,734	3,301
K0507 CSS-22	PU Activate Switch P/U				6,400 Time from ECC	
K0013	Engine Cutoff PU (New time reference)			0	0	0
		K0005	Mainstage Control Solenoid Enrg D/O	Within 10 ms of K0140	4	4
		K0006	Ignition Phase Control Solenoid Enrg D/O	Within 10 ms of K0140	4	4

* Within 5,000 ms of K0005 (Normally = 500 ms)

** One of these signals must be received within 4,410 ±260 ms from K0021 P/U, or cutoff will be initiated. Signal occurs when LOX injection pressure is 500 ±30 psig.

TABLE 8-4 (Sheet 4 of 5)
ENGINE SEQUENCE S-IVB-202 FLIGHT

Control Events		Contingent Events			Actual Time (ms)	
Meas. No.	Event and Comment	Meas. No.	Event and Comment	Nominal Time from Specified Reference	From ESC	From Spec. Ref.
		K0020	ASI LOX Valve Open D/O	200 ms from K0013	2	2
		K0120	Main Oxidizer Valve Open D/O	50 ±15 ms from K0005	38	34
		K0117	Gas Generator Valve Open D/O	110 ±30 ms from K0006	34	30
		K0118	Main Fuel Valve Open D/O	90 ±20 ms from K0006	49	45
		K0121	Main Oxidizer Valve Closed P/U	130 ±15 ms from K0120	351	313
		K0116	Gas Generator Valve Closed P/U	500 ms from K0006	251	247
		K0119	Main Fuel Valve Closed P/U	225 ±25 ms from K0118	551	502
K0158	*Mainstage Press. Switch A Depress. P/U			*	113	
K0159	Mainstage Press. Switch B Depress. P/U			*	113	
K0191	Mainstage OK D/O			*		
K0007	Helium Control Solenoid Enrg D/O			1,000 ±110 ms from K0013	940	940
SS-22 K0507	PU Activate Switch D/O			N/A		

* Signal drops out when pressure reaches 425 ±25 psig.

TABLE 8-4 (Sheet 5 of 5)
ENGINE SEQUENCE S-IVB-202 FLIGHT

Control Events		Contingent Events			Actual Time (ms)	
Meas. No.	Event and Comment	Meas. No.	Event and Comment	Nominal Time from Specified Reference	From ESC	From Spec. Ref.
		K0125	Oxidizer Turbine Bypass Valve Closed D/O	8,000 ms from K0005	7,034	NA
		K0124	Oxidizer Turbine Bypass Valve Open P/U	10,000 ms from K0005	8,851	NA
K0126	LOX Bleed Valve Closed D/O			15,000 ms from K0005	3,350	NA
K0127	LH2 Bleed Valve Closed D/O			15,000 ms from K0005	3,849	NA

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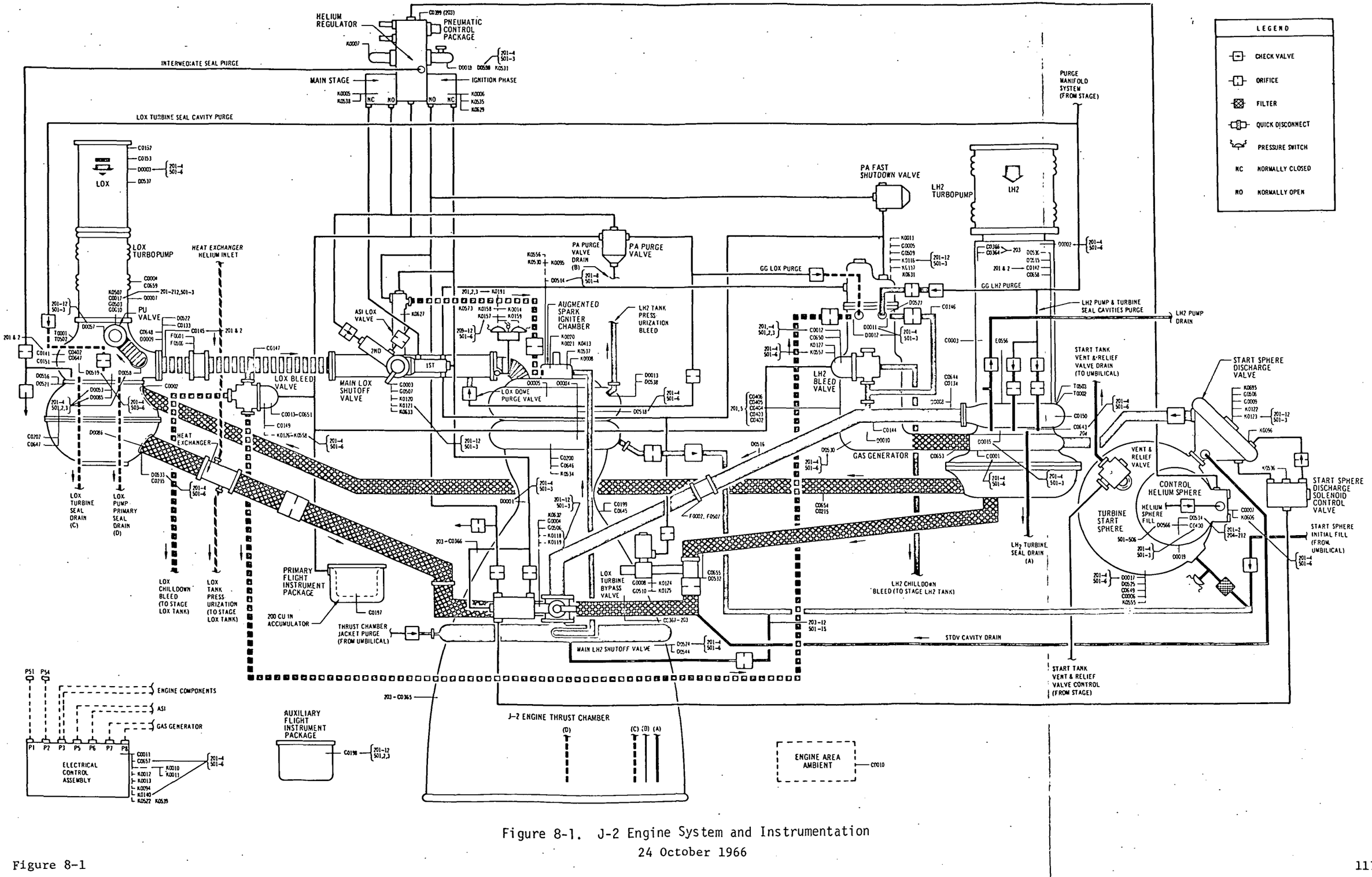


Figure 8-1. J-2 Engine System and Instrumentation
24 October 1966

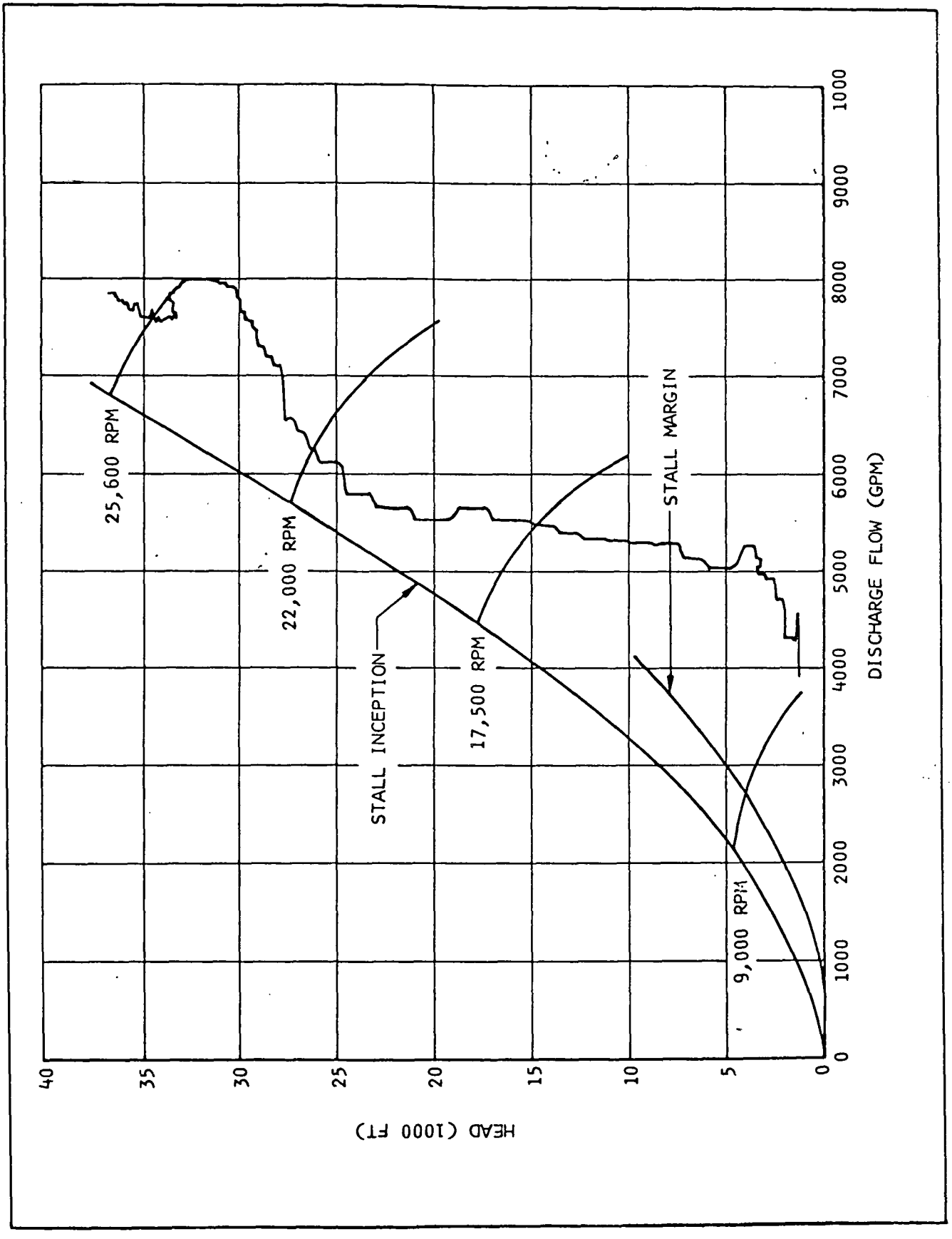


Figure 8-2. LH2 Pump Performance During Engine Start

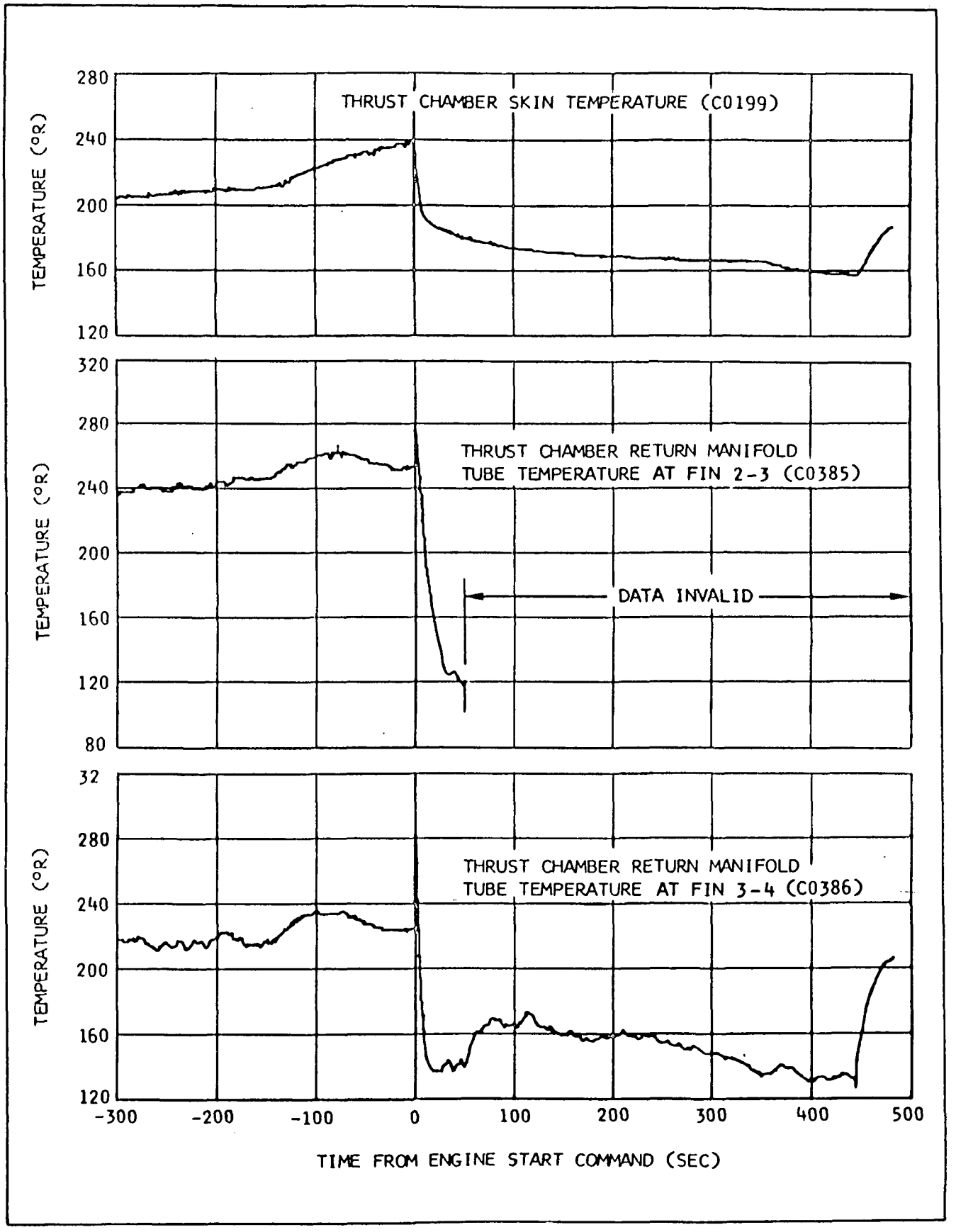
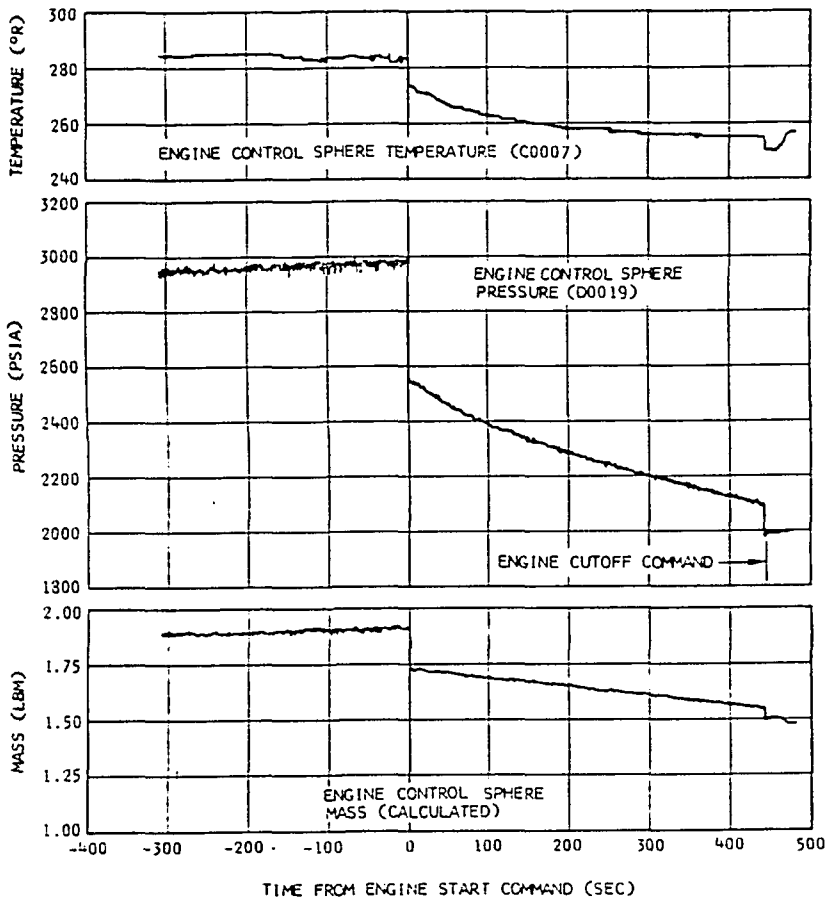


Figure 8-3. Thrust Chamber Temperature Profile

24 October 1966



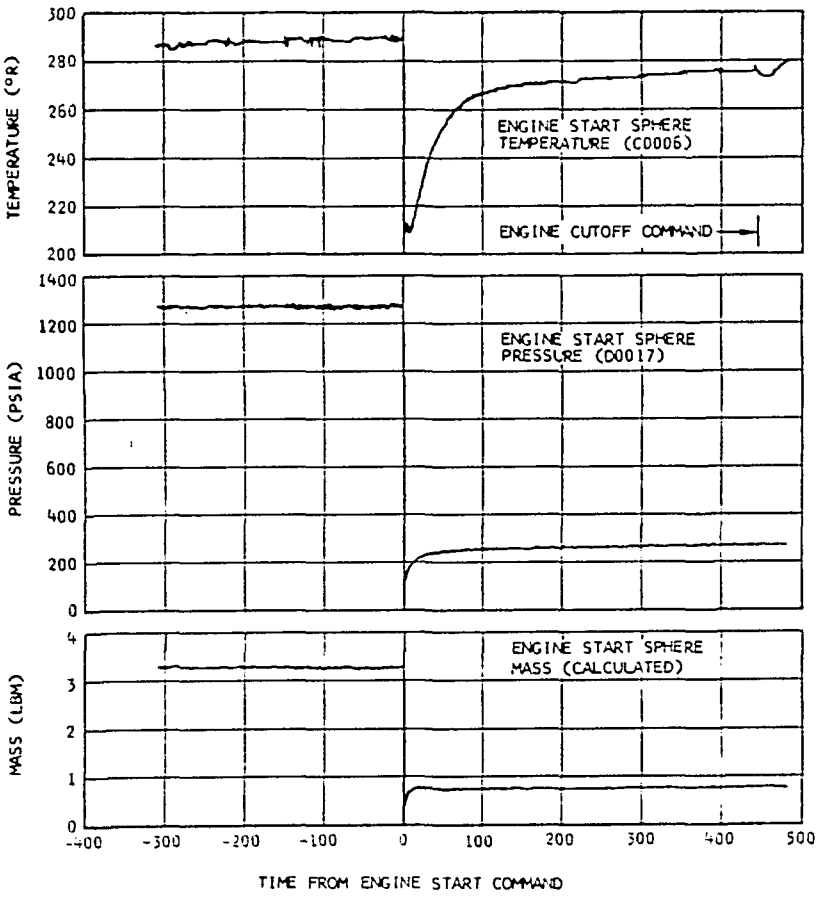


Figure 8-4. Engine Start and Control Sphere Performance

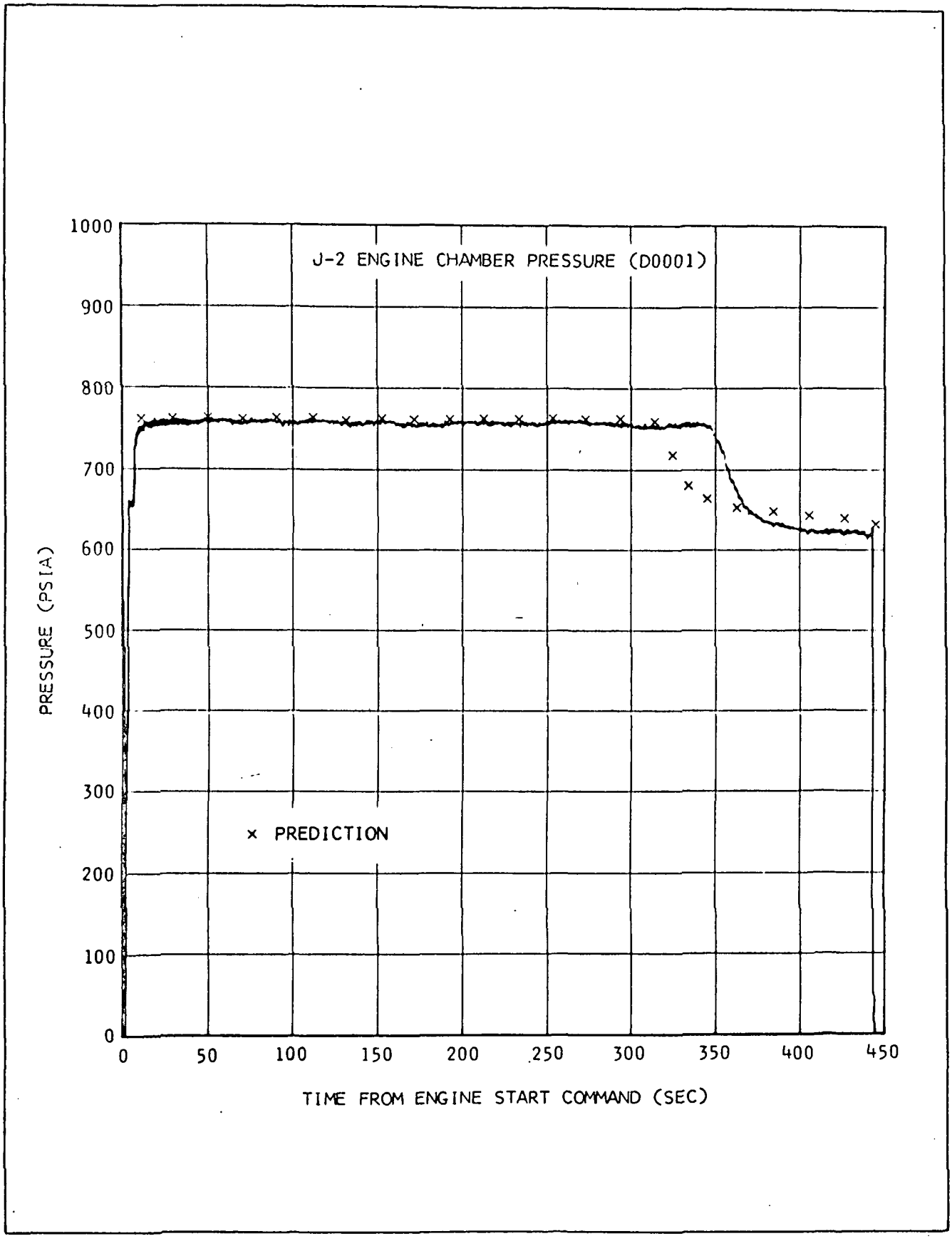


Figure 8-5. J-2 Engine Chamber Pressure

24 October 1966

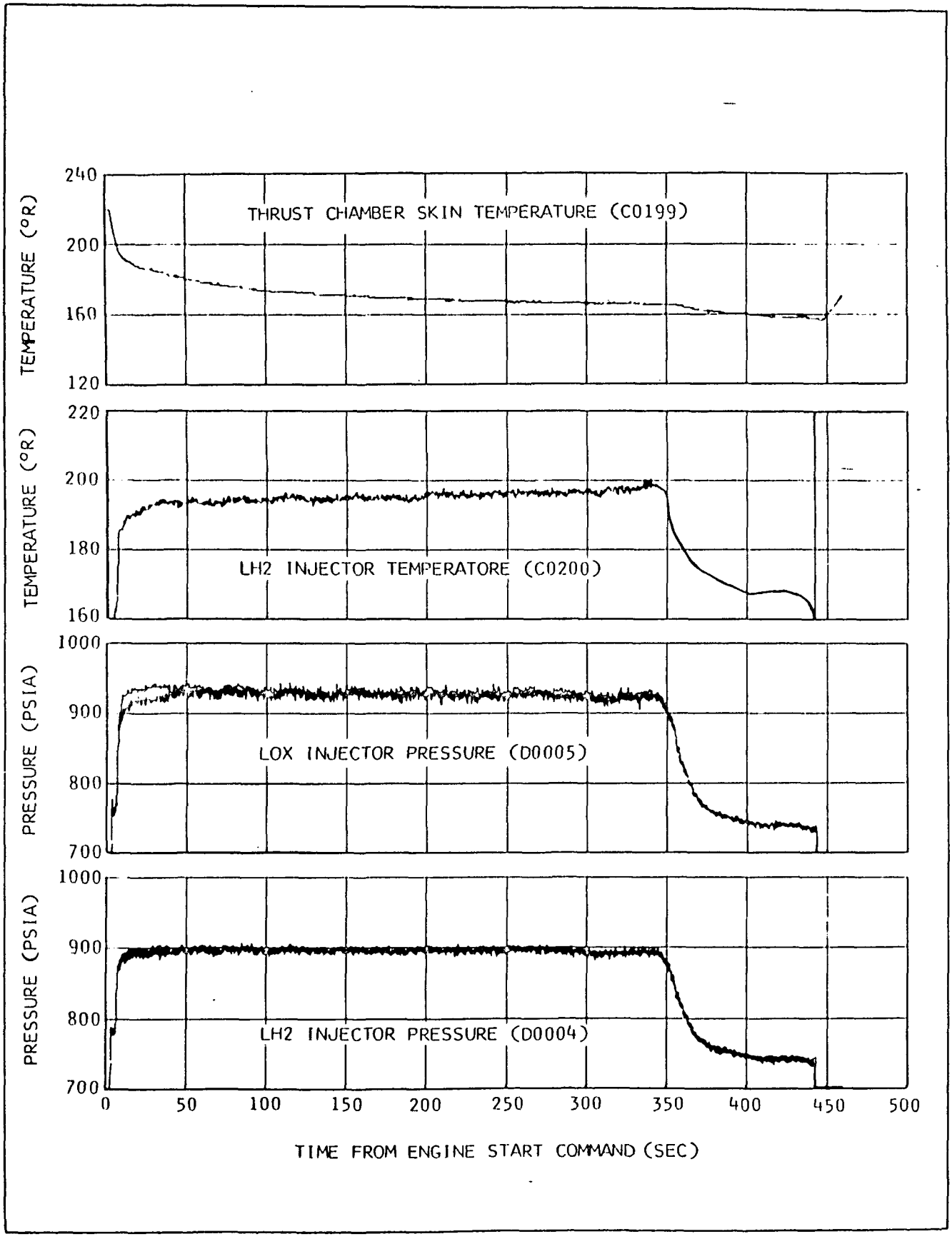


Figure 8-6. J-2 Engine Injector Supply Conditions

24 October 1966

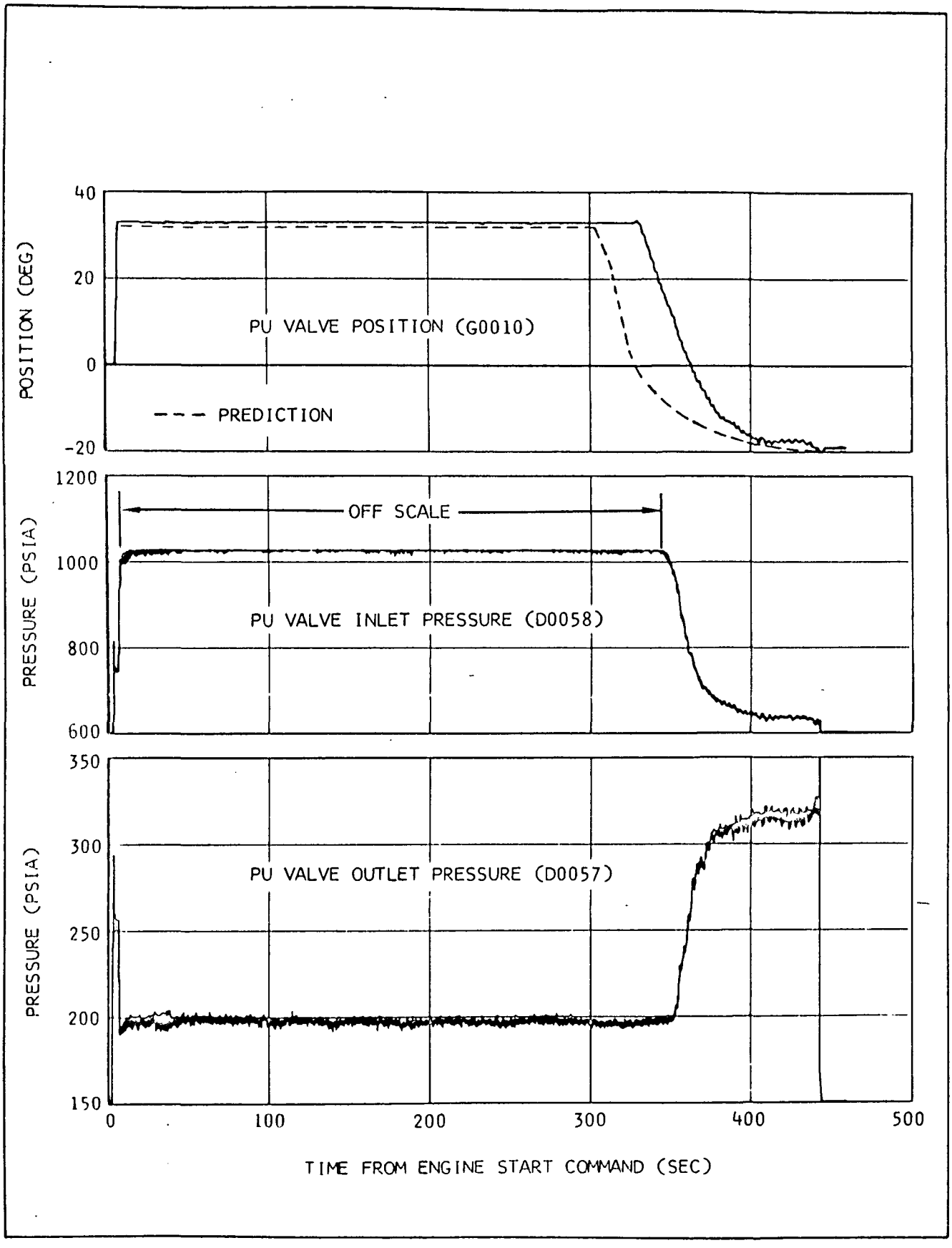


Figure 8-7. PU Valve Operation

24 October 1966

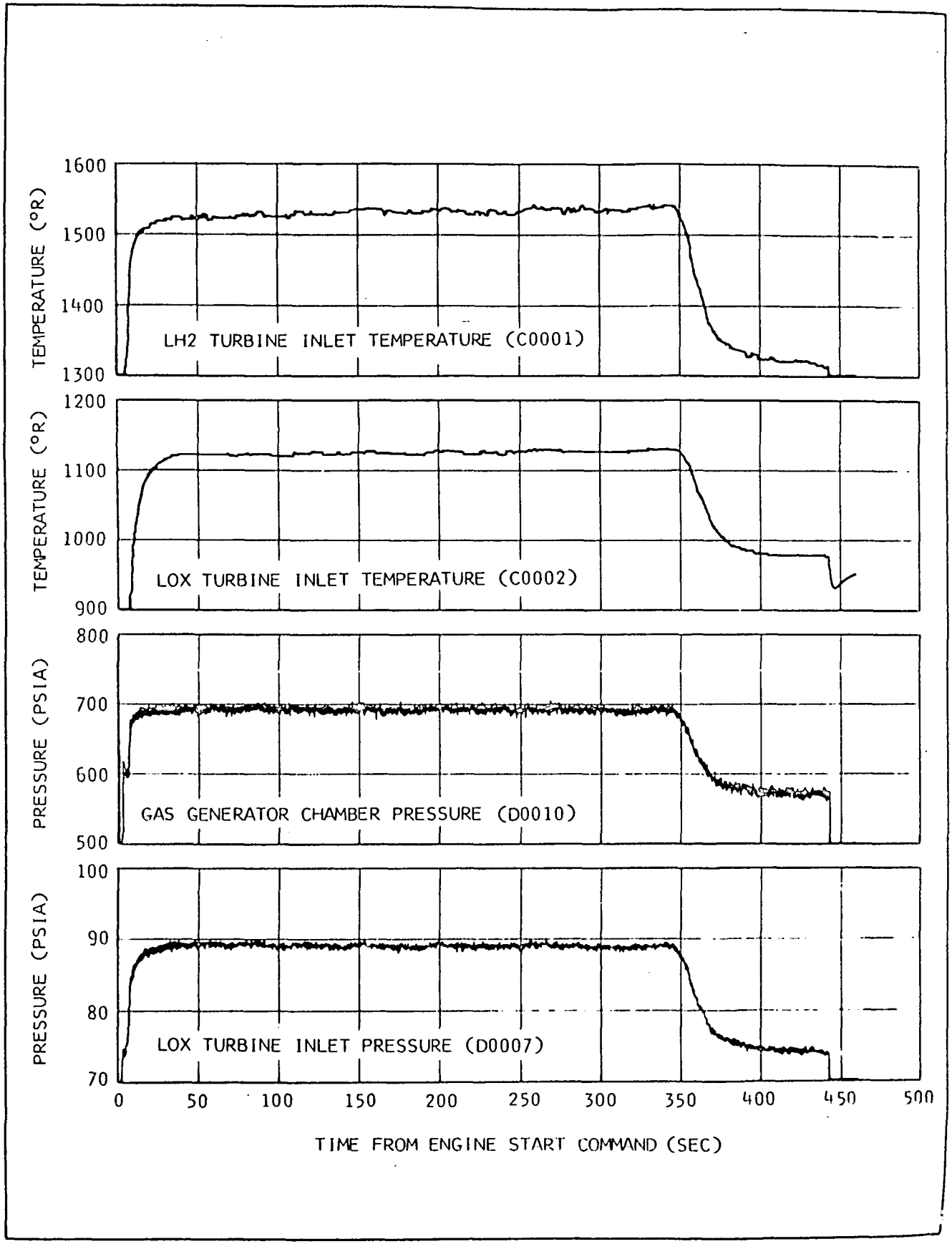


Figure 8-8. Turbine Inlet Operating Conditions

24 October 1966

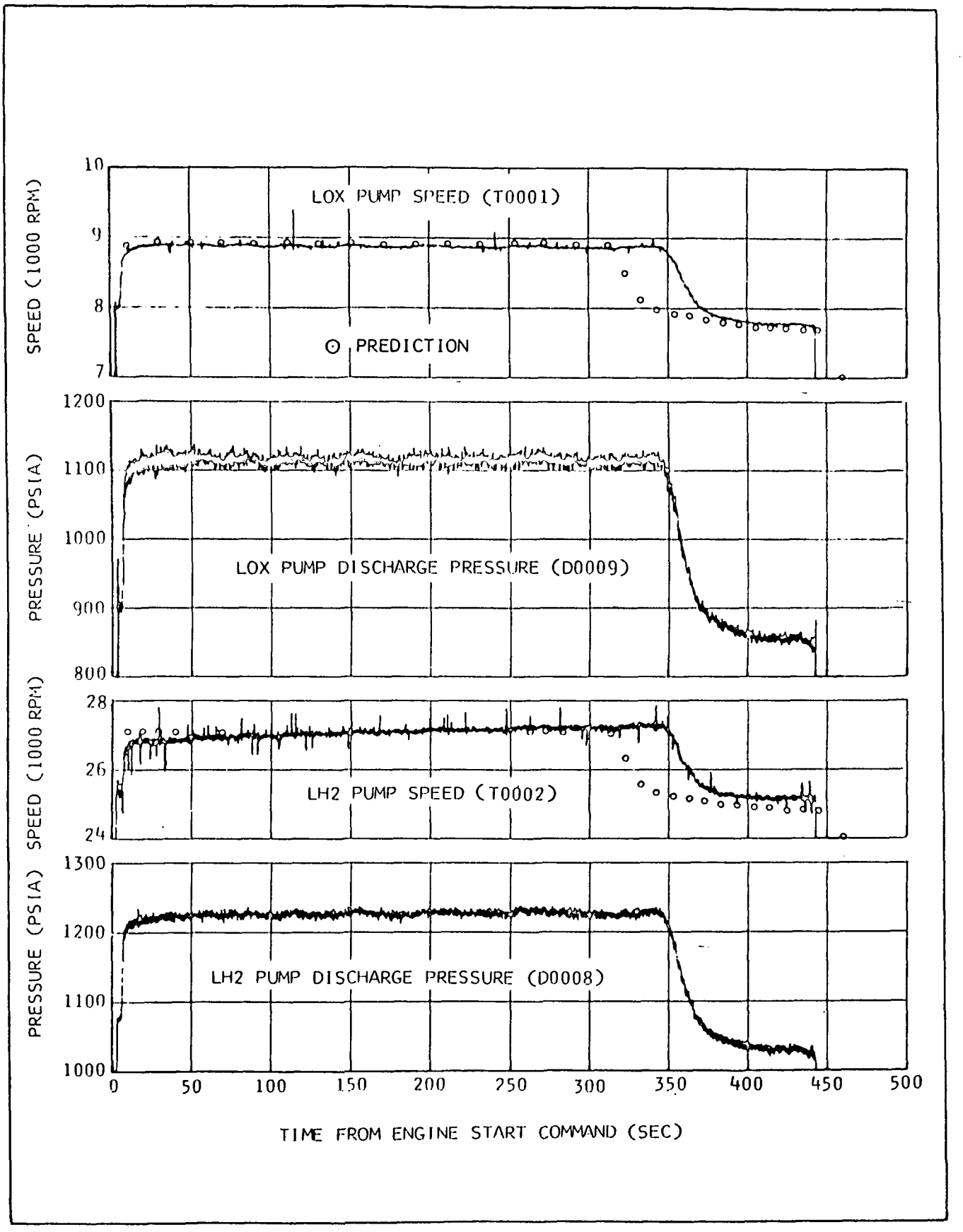


Figure 8-9. J-2 Engine Pump Operating Conditions

24 October 1966

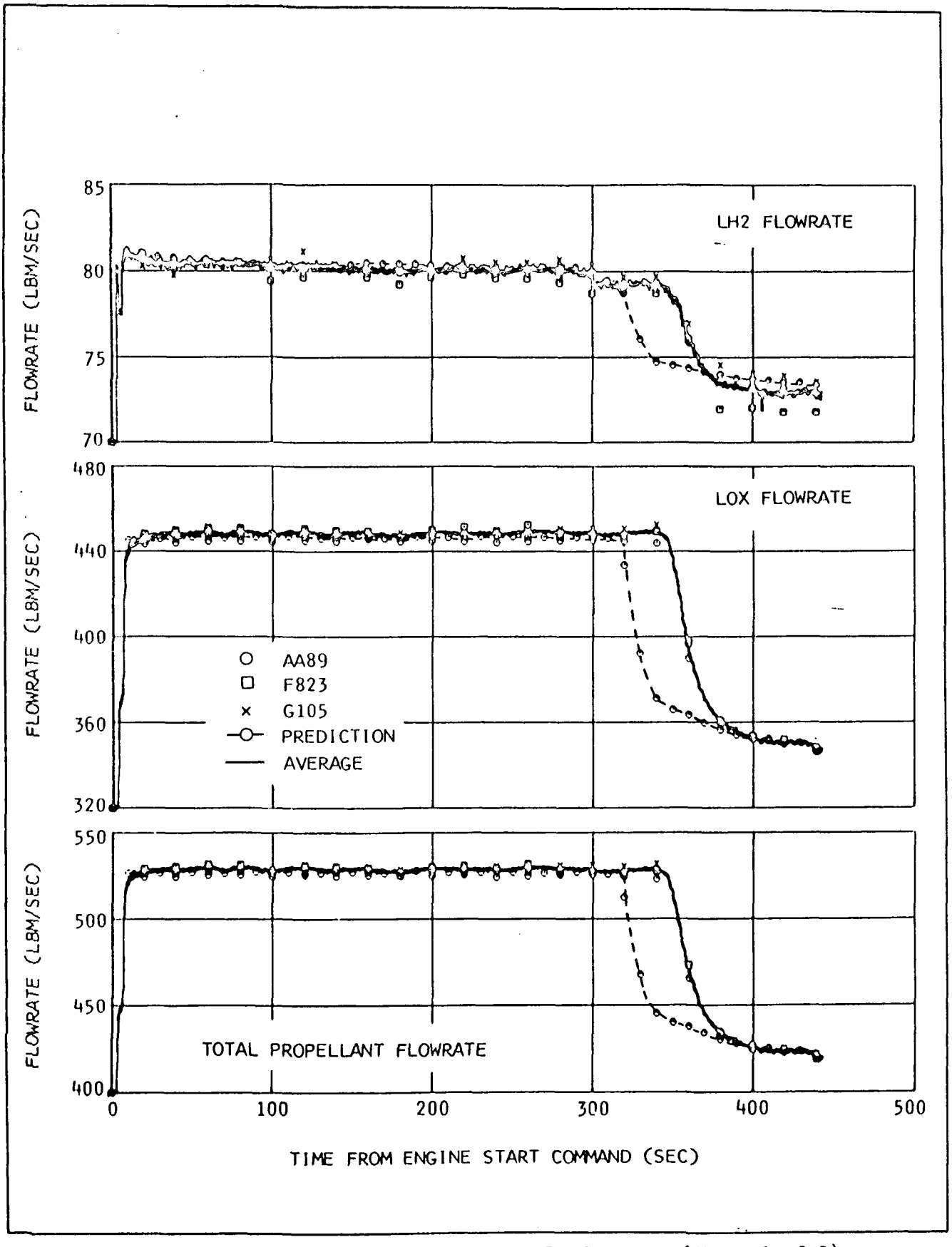


Figure 8-10. Engine Steady State Performance (Sheet 1 of 2)

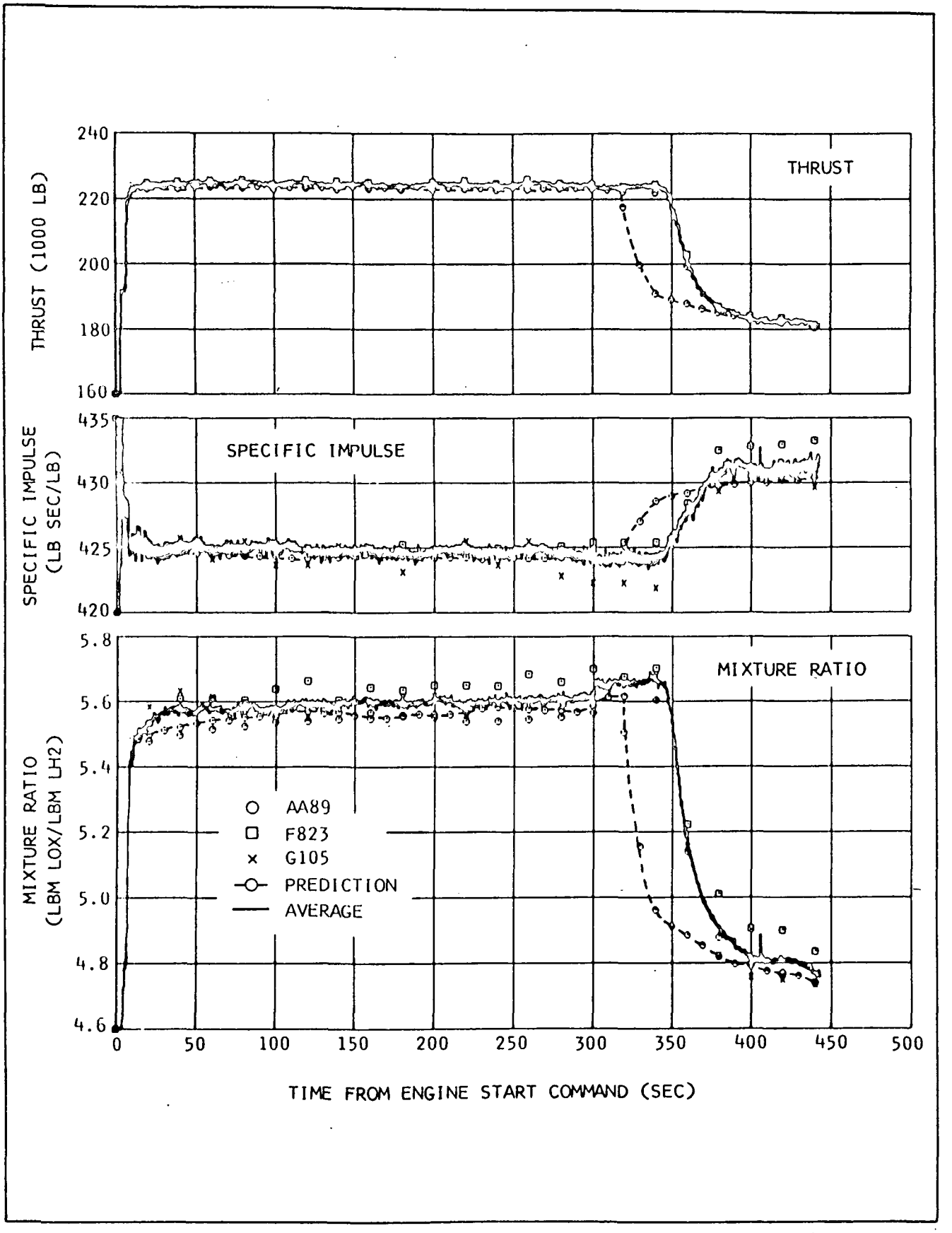
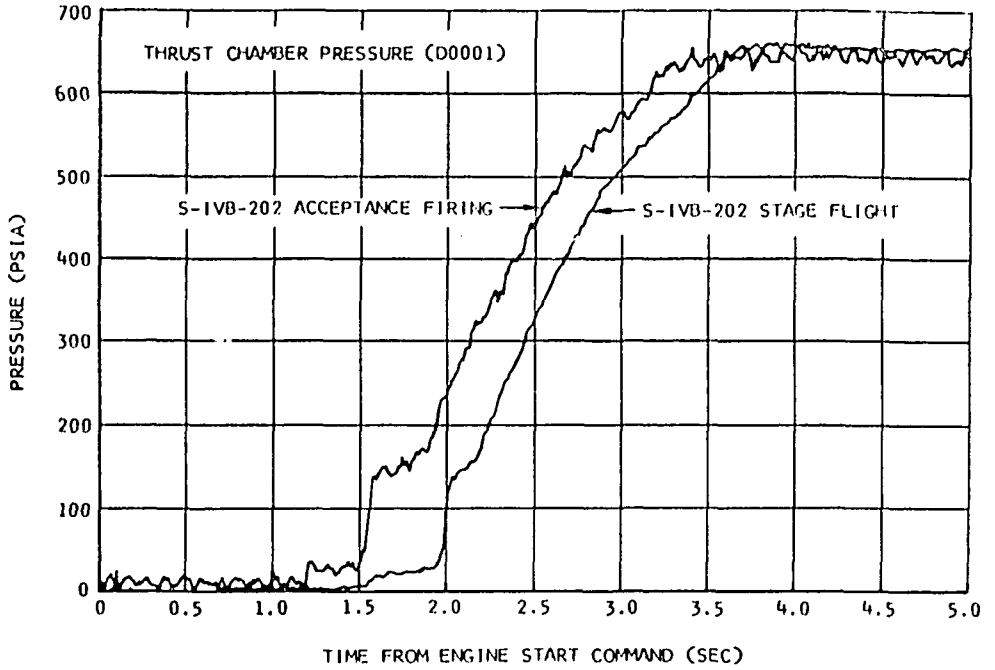


Figure 8-10. Engine Steady State Performance (Sheet 2 of 2)

24 October 1966



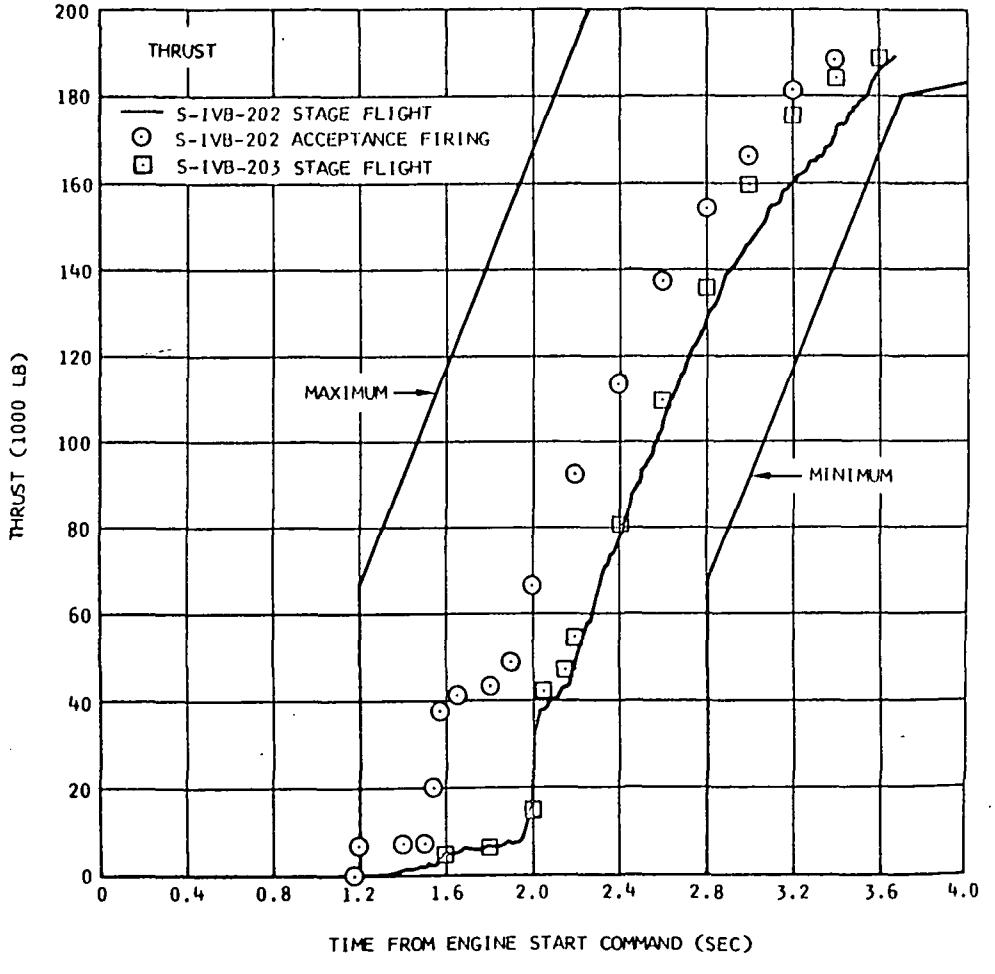


Figure 8-11. Engine Start Transient Characteristics

24 October 1966

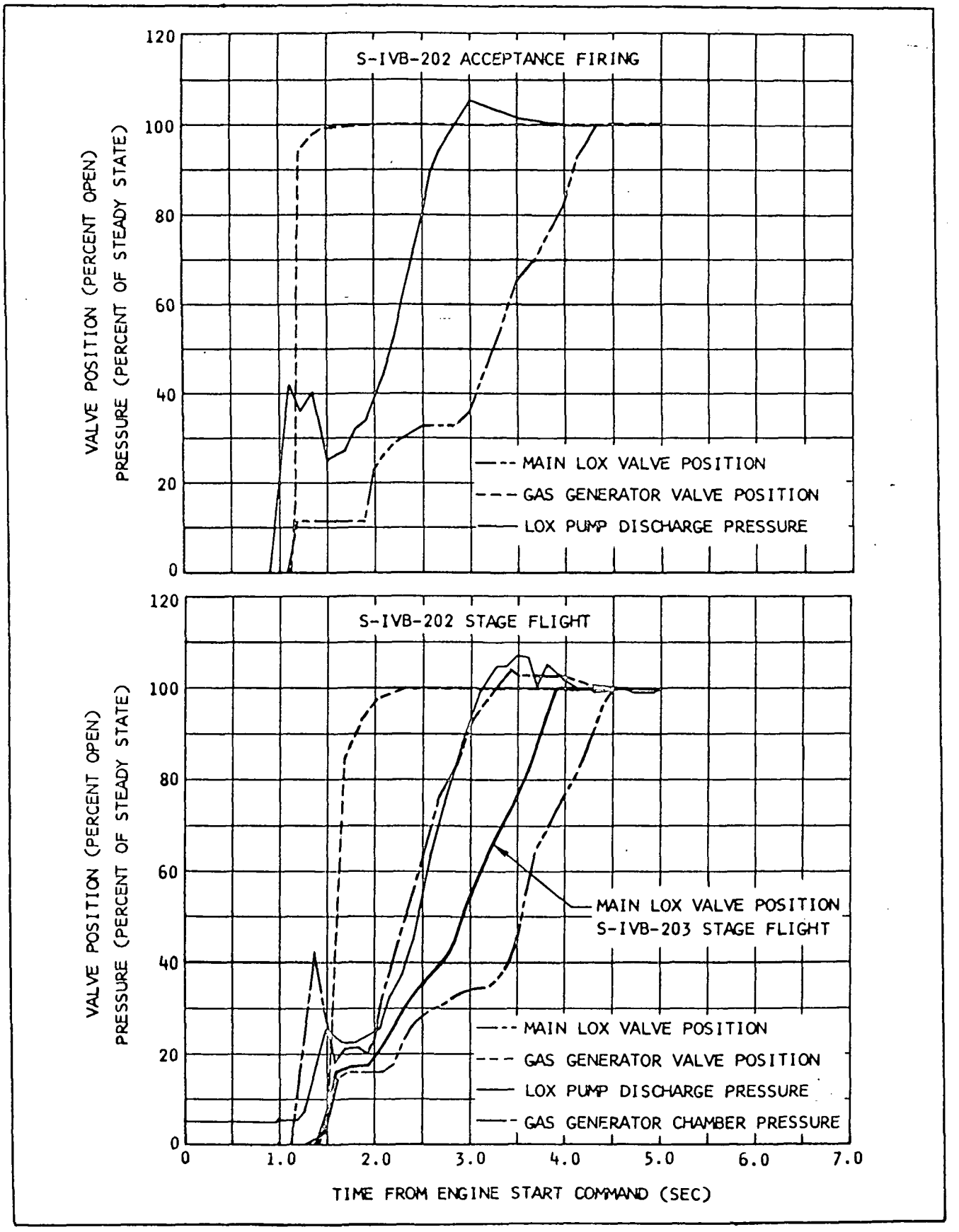
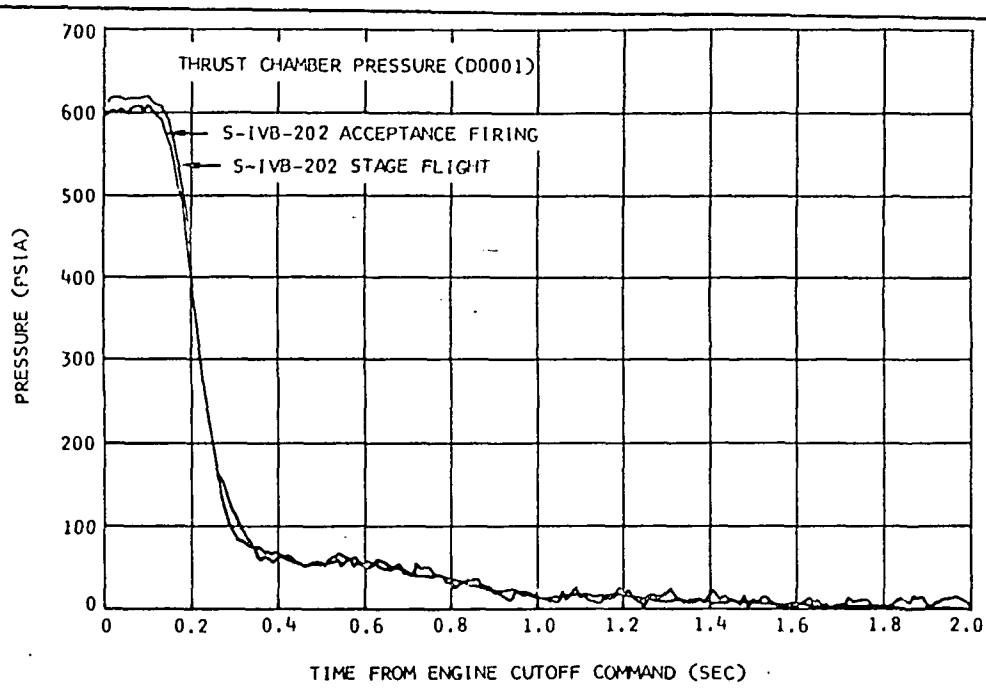


Figure 8-12. Engine LOX System Start Transient

24 October 1966



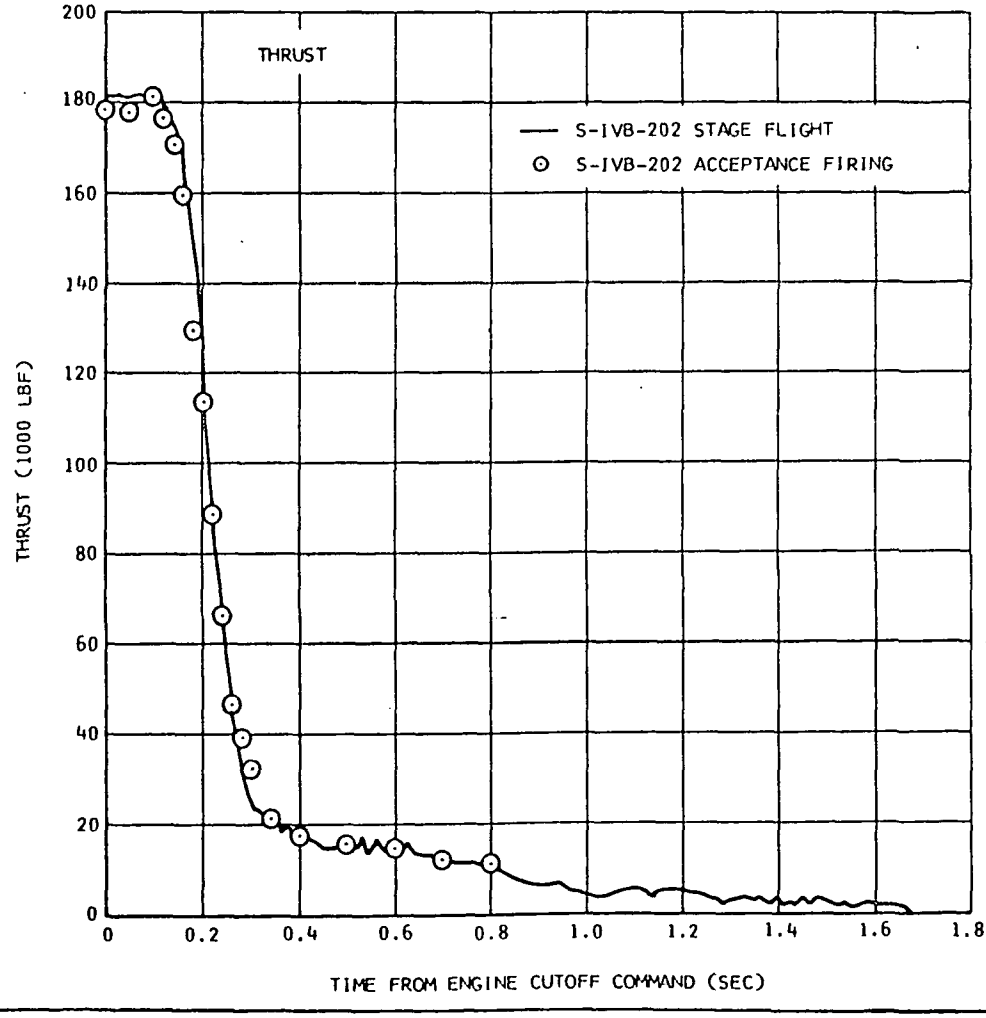


Figure 8-13. Engine Cutoff Transient Characteristics

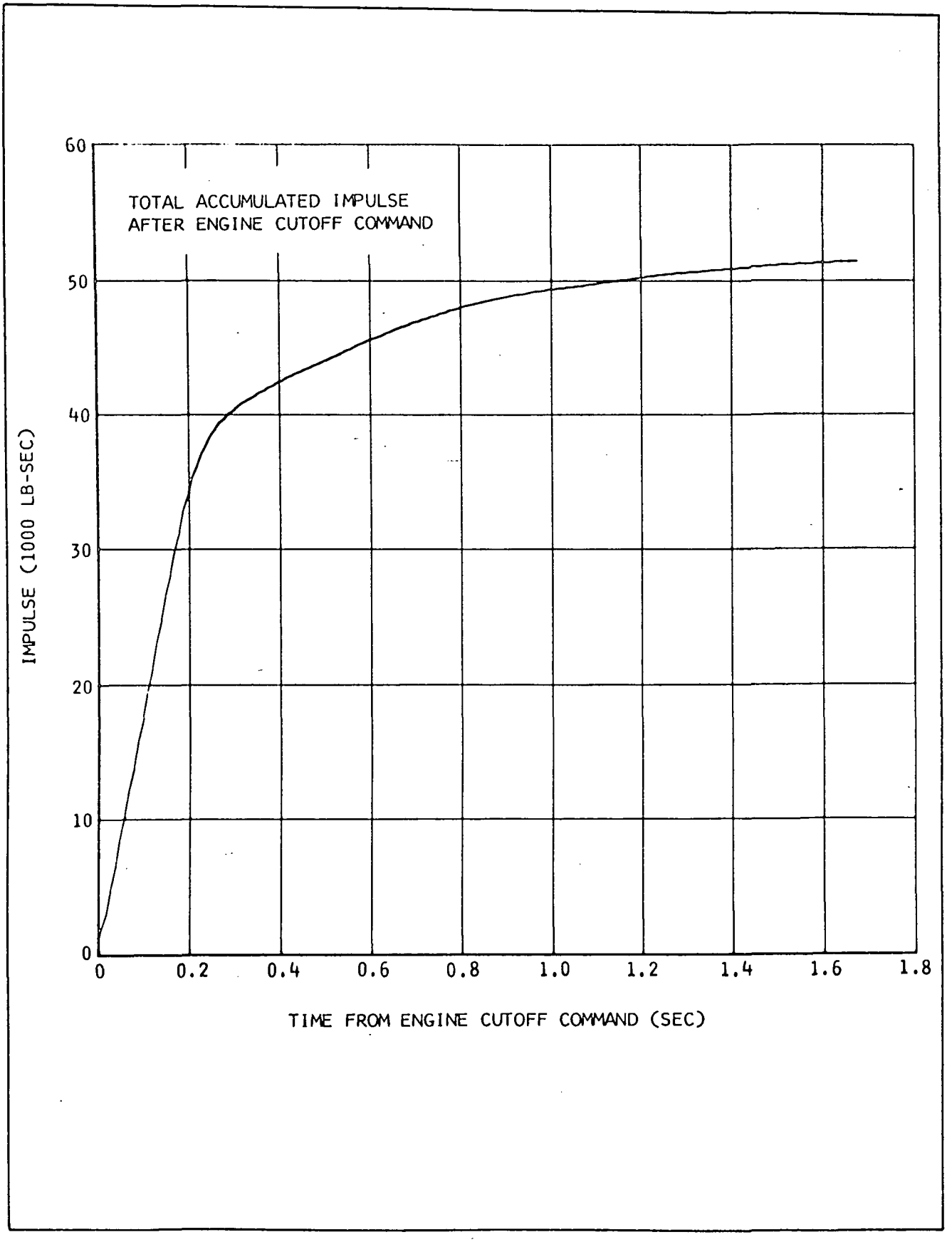


Figure 8-14. Total Accumulated Impulse After Engine Cutoff Command

24 October 1966

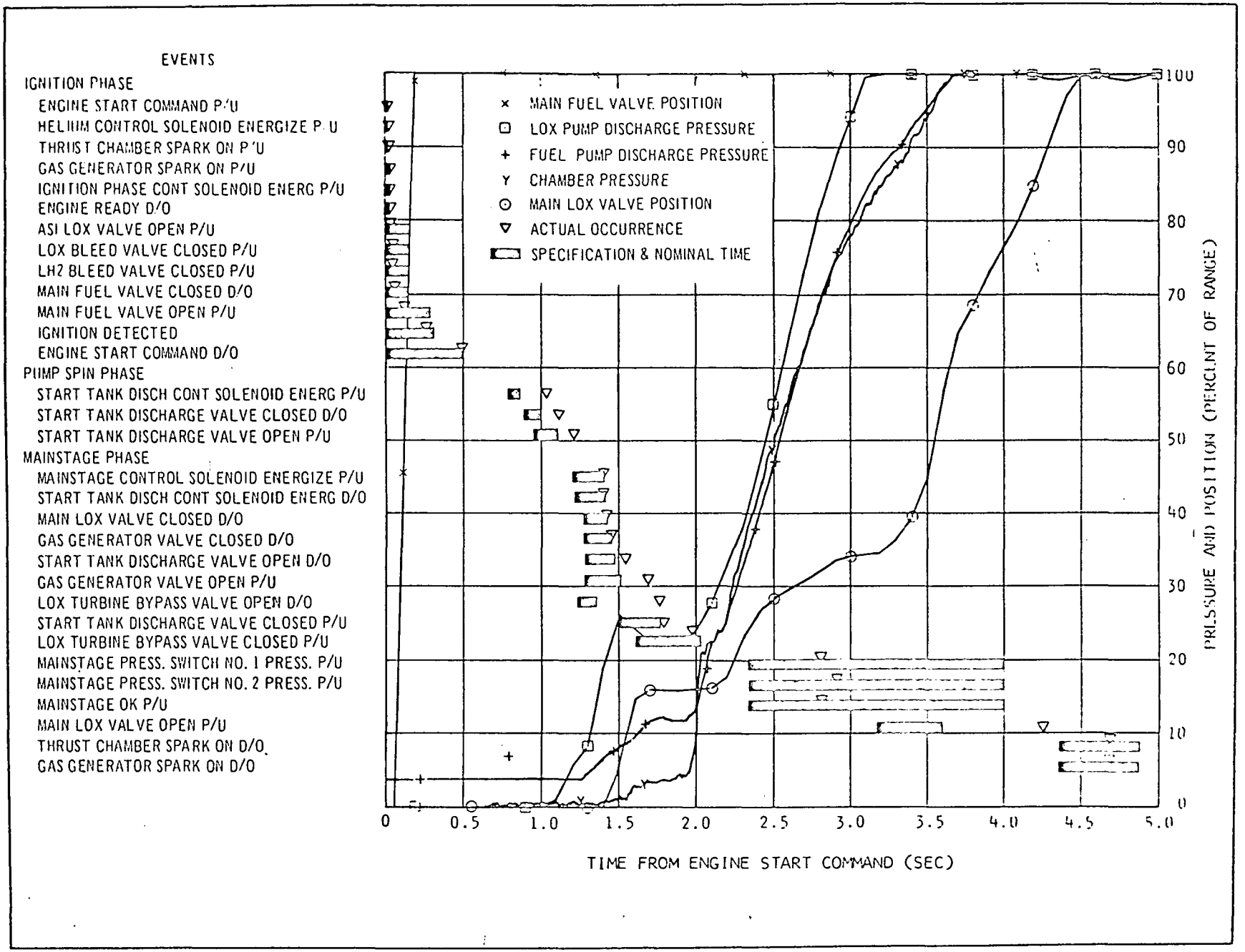


Figure 8-15. Engine Start Sequence

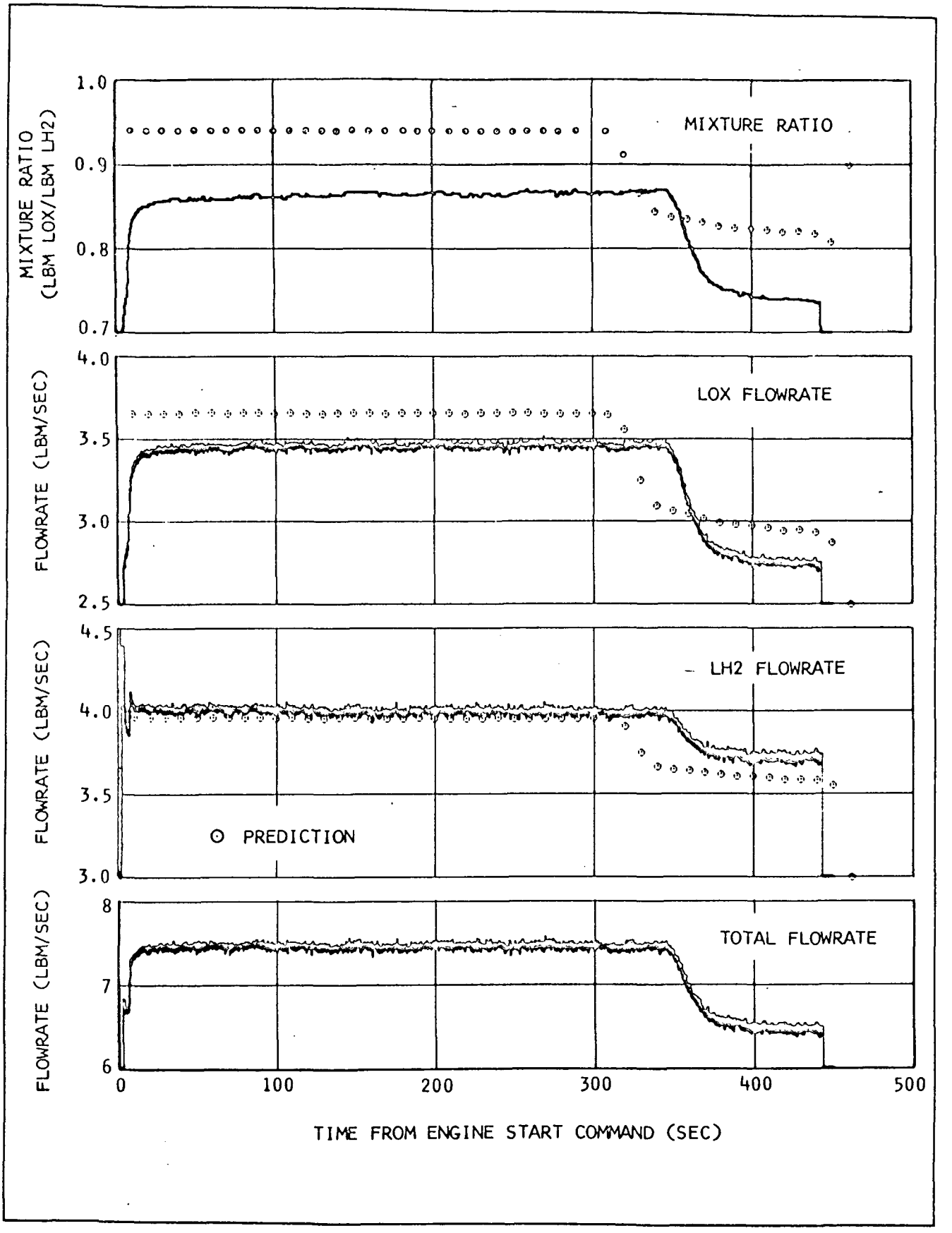


Figure 8-16. Gas Generator Performance

24 October 1966

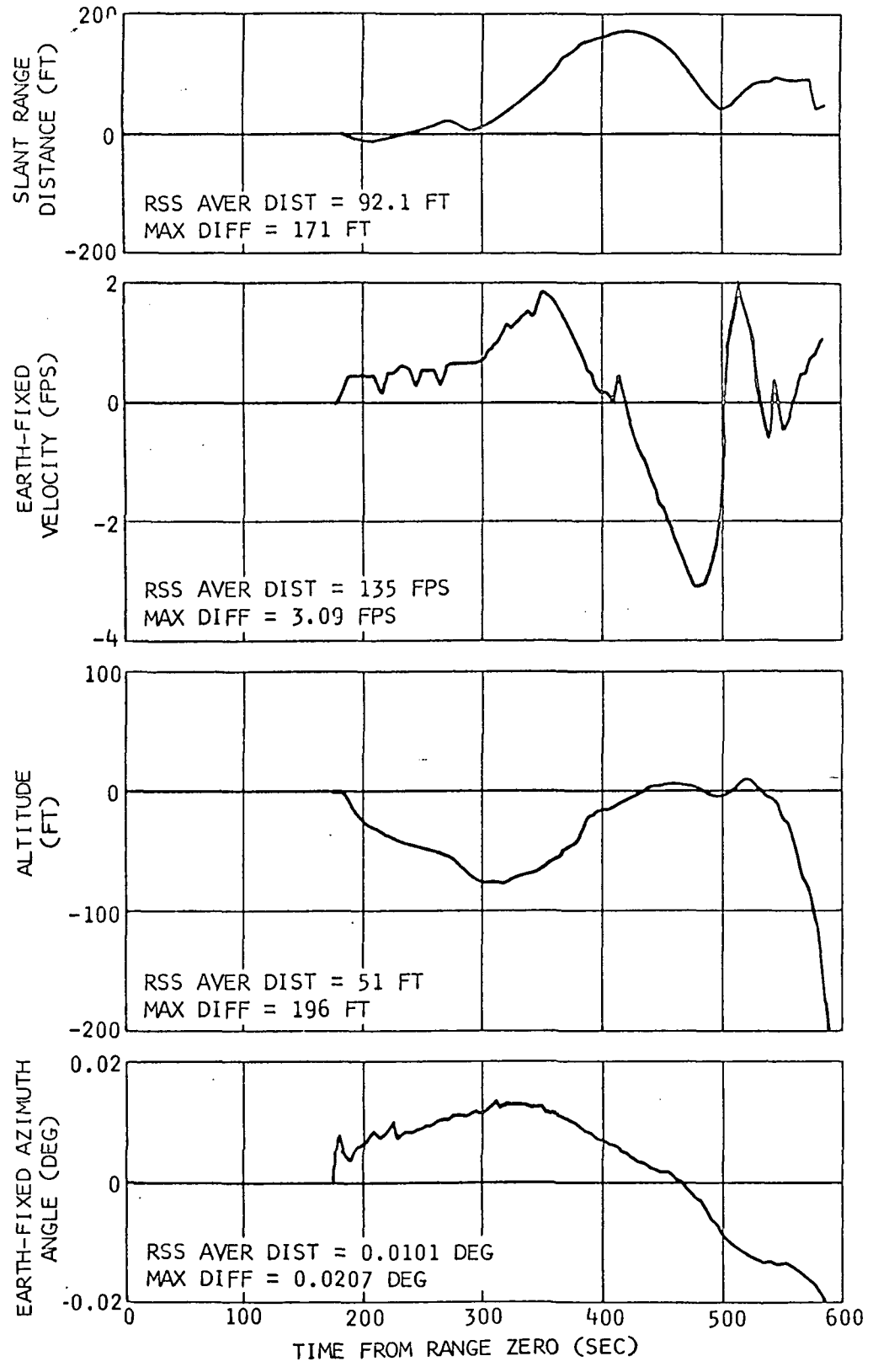


Figure 8-17. AS-202 Flight Simulation Residuals (Actual Minus Simulated)

24 October 1966

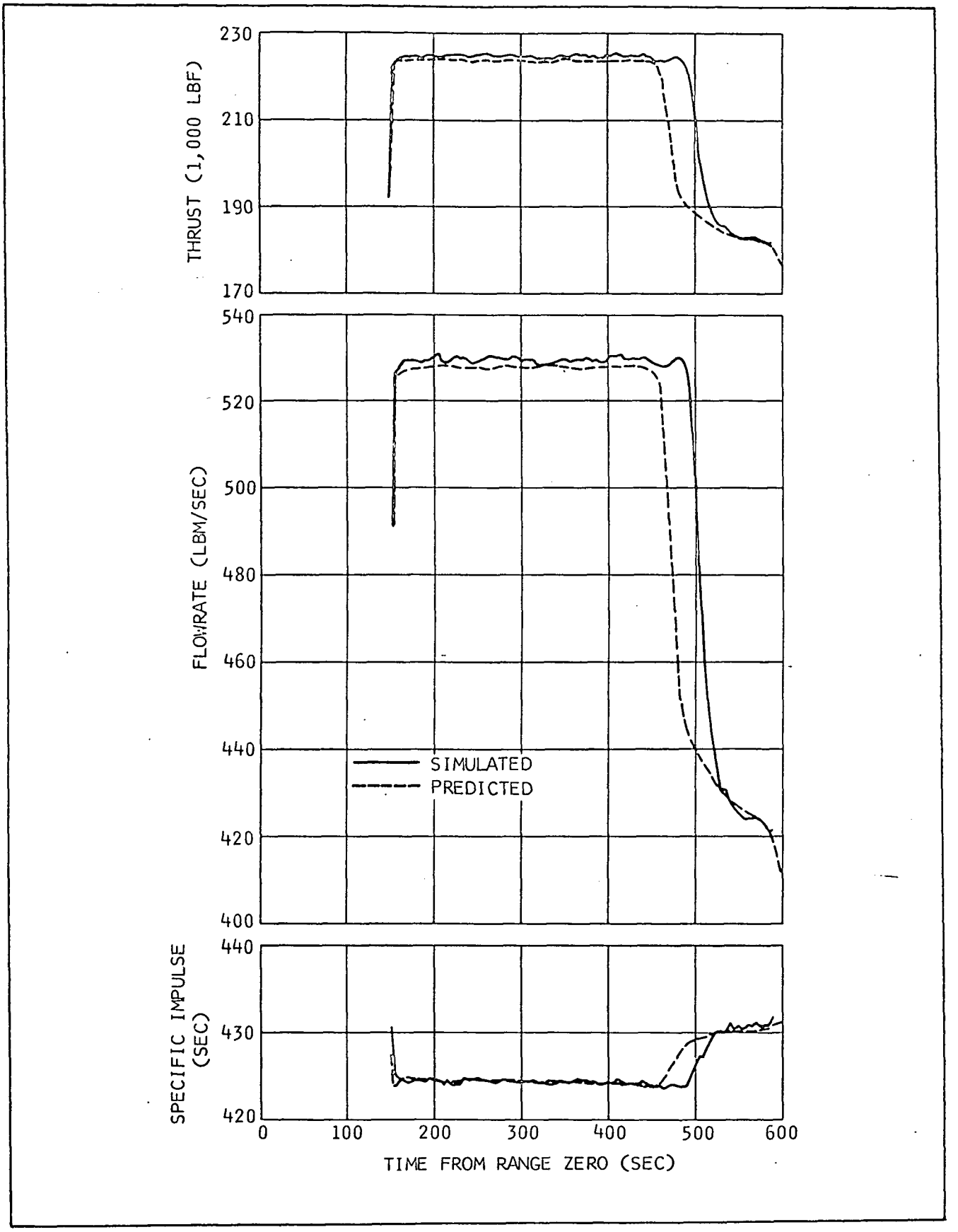


Figure 8-18. Predicted and Simulated Propulsion Parameters

24 October 1966

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9. SOLID ROCKET PERFORMANCE

The solid rocket motors on the AS-202 launch vehicle satisfactorily accomplished their intended purpose. The S-IB was separated from the S-IVB stage by the retrorockets, and the S-IVB propellants were settled prior to J-2 engine ignition by the ullage rockets.

9.1 Ullage Rockets

Ullage rocket performance was satisfactory and all motors were jettisoned properly. The Ullage Rocket Ignition Command was given at RO +144.030 sec, and the Jettison Command was given at RO +156.221 sec.

Table 9-1 presents the individual rocket motor performance parameters as defined in the Thiokol Chemical Co. model specification, SP-544A, dated 29 November 1965. A comparison of these data with nominal performance limits indicates all these motors performed within design specifications and provided satisfactory propellant settling for J-2 engine start. Figure 9-1 presents the thrust profile during motor firing.

9.2 Retrorockets

The retrorockets mounted on the S-IVB aft interstage responded to the ignition command at RO +144.27 sec and satisfactorily separated the S-IB stage from the S-IVB stage. However, data indicate that one retrorocket malfunctioned. The chamber pressure versus time curves from the retrorockets show that all four motors performed within specification limits until the abrupt and premature drop in chamber pressure of motor S/N PV16-521-10 (figure 9-2).

Burntime of motor S/N PV16-521-5 was slightly short, but within specification requirements. Photography of the S-IB/S-IVB stage separation correlated with the chamber pressure data verifying the two motors short burntimes.

Conclusions at this time indicate that an additional area of gas discharge developed in a manner which produced explosive decompression of the combusion chamber. The most likely failure of this type would be a motor case burn-through. Hot spots and/or burn-through holes are thought to have occurred only near the end of propellant burntime when

the S-IVB stage had separated from the S-IB stage by several feet. It appears unlikely that the suspected malfunction of a retrorocket on the S-IB stage could adversely affect the mission of the S-IVB stage. The retrorocket configuration is shown on figure 3-2.

9.2.1 Motor Performance

The chamber pressure versus time curves from the four Thiokol TE-M-29-4 (DAC P/N 1A59670-1) retrorockets show that all four motors started within 0.02 sec of each other. Burntime of motor S/N PV16-532-6 and -7 displayed normal operation throughout; -6 motor was 0.63 percent short of theoretical burntime and -7 motor was 1.02 percent longer than the theoretical burntime. Burntime of motor S/N PV16-521-5 was slightly short (-2.63 percent) but within the specified requirements. Motor S/N PV16-521-10 shut down 0.17 sec early giving a 10.3 percent deviation from model specification values, (table 9-2). Several other peculiarities in the pressure-time trace of -10 motor as well as the unusual abrupt shutdown are discussed below.

The pressure versus time curve of motor -10 appeared unusual in the following respects, although none of these peculiarities could be considered to be outside specification limits:

a. There was a double ignition peak, the second peak being approximately 100 psia higher than the first.

b. During the first 0.8 sec of operation, the chamber pressure remained higher than any of the other three motors. Then, during the next 0.2 sec, the chamber pressure dropped rapidly from 1,885 psia to 1,639 psia and leveled out at approximately 1,500 psia by the time of abrupt pressure drop.

The following peculiarities of the pressure versus time curve during the cutoff transients are considered to be indications of a malfunction.

a. At 1.35 sec after ignition, the pressure suddenly dropped at a rate of 21,500 psi/sec, as compared to 8,600 psi/sec in the steepest part of a normal tail-off.

b. There was no rounding of the pressure trace from the 1,500 psi level into the tail-off phase as normally occurs. The sharpness of this knee of the curve, combined with the above observed high rate of pressure drop suggests a possible explosive decompression of the motor case.

c. After the initial loss of about 500 psi (in about 0.023 sec), the pressure time trace became more gradual in slope than a normal tail-off. This could be due to the remaining propellant burning with excessive area due to fracturing caused by the explosive decompression.

9.2.2 Failure Analysis

Taking into account only the TE-M-29-4 and -5 rocket motors built for DAC, there have been 11 qualification test firings, five production quality acceptance firings, and 12 motors used in Saturn IB/S-IVB flights. Of these, three were known to have hot spots. Hot spots occurring in flight without a burn-through would go undetected. One flight motor, S/N PV16-521-10 appears to have had a motor case burn-through.

The possible modes of failure of motor -10 were: motor case burn-through, loss of nozzle throat, loss of propellant (slivers), chamber pressure sensing line failure, and chamber pressure transducer failure. A discussion of each possible mode of failure follows:

a. The motor case burn-through was placed first on the list because hot spots appeared at the nozzle end of the motor case on three of the eleven motors fired in the qualification test program. This indicated that burn-through possibly was imminent. The very high rate of pressure loss shown in the flight data could be explained by the sudden occurrence of an extra opening through which exhaust gases could escape. It has been calculated that the extra area (beyond the area of the throat) required to produce the 21,500 psi/sec pressure drop is 21.7 in^2. The shape of the latter part of the pressure tail-off, which is even more gradual than a normal tail-off, could occur following an explosive decompression

severe enough to fracture the propellant, thereby exposing additional burning surface.

b. Sudden loss of the nozzle throat could also explain the very high rate of pressure loss and the explosive decompression might cause some cracking of the remaining propellant to explain the gradual pressure loss in the latter part of the tail-off. This theory is discounted primarily on the basis that the graphite throat is so massive and so thoroughly locked in place that an instantaneous loss of the entire throat is inconceivable.

c. Sudden loss of propellant, possibly in the form of slivers, could cause a sudden drop in pressure due to loss of burning surface. Assuming the lost propellant could pass through the nozzle without causing a momentary restriction, since no momentary pressure rise was recorded, the rate of pressure loss should be no greater than in a normal tail-off. This failure mode cannot explain either the initial high rate of pressure loss nor the subsequent lower than normal rate of pressure loss.

d. A failure of the chamber pressure sensing line would result in the chamber pressure transducer being disconnected from the motor. In this situation, the recorded loss of pressure would be as abrupt as actually recorded, but it would continue downward to zero at a very high rate with no indication of a gradual tail-off.

e. A failure of the chamber pressure transducer should result in a loss of signal from that transducer. This did not occur.

Color photography of separation of the S-IVB stage from the S-IB stage was taken by a camera located within the S-IVB aft interstage, which stays with the S-IB stage at separation. These pictures show the tips of the retrorocket exhaust, one of which disappeared before the others. The location of the motor with the exhaust plume that disappeared early has been correlated to the location of motor S/N PV16-521-10. The location of the second exhaust plume to disappear has been correlated

to the location of motor S/N PV16-521-5. The remaining two exhaust plumes disappeared together. The effects of retrorocket performance on separation are discussed in section 15.

These facts indicate that an actual motor failure of S/N PV16-521-10 did occur with the cause stemming from either item a, b, or c listed above. The most likely possibility appears to be that a motor case burn-through occurred.

The other motor, S/N PV16-521-5, using -521 propellant mix displayed some peculiarities also. They were as follows:

a. The ignition peak was 230 psi higher than any of the other motors and near the upper allowable limit.

b. From the ignition peak onward, the pressure dropped continuously, never becoming constant.

The chamber pressure versus time traces revealed that the burn rate of the -521 propellant mix was probably greater than that of the -532 mix. This was confirmed by Thiokol data from the sub-scale propellant test motor firings.

A complete explanation of the above peculiarities during the start and steady-state portions of the firing cannot be made at this time, but it is evident that both batch-to-batch variations and motor-to-motor variations are displayed in these data.

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TABLE 9-1
ULLAGE ROCKET PERFORMANCE - AS-202

PARAMETER	MOTOR A (pos I-II)	MOTOR B (pos IV-I)	MOTOR C (pos II-III)	NOMINAL PERFORMANCE LIMITS	
				MAXIMUM	MINIMUM
Action time* (sec)	5.89	5.89	5.95	6.08	5.01
Burntime** (sec)	3.75	3.75	3.71	4.10	3.54
Maximum chamber pressure (psia)	1,000	1,000	994	1,220	900
Maximum ignition chamber pressure (psia)	1,066	1,081	1,058	1,470	--
Average action time chamber pressure (psia)	713	716	697	880	680
Average burntime chamber pressure (psia)	981	985	971	1,100	890
Maximum thrust (lbf)	3,470	3,470	3,450	4,150	2,600
Maximum ignition thrust (lbf)	3,700	3,750	3,670	5,100	--
Average action time thrust (lbf)	2,474	2,486	2,420	3,045	2,345
Average burntime thrust (lbf)	3,404	3,417	3,368	3,786	3,090
Action time total impulse (lb-sec)	14,570	14,642	14,400	15,595	14,335
Burntime total impulse (lb-sec)	12,764	12,812	12,500	13,590	12,500

* The time between 10 percent of the maximum chamber pressure during the start transient and 10 percent of the maximum chamber pressure during the cutoff transient.

** The time required for the pressure to rise from 10 percent to maximum and fall to 75 percent of maximum.

TABLE 9-2
COMPARATIVE PERFORMANCE OF RETROROCKETS

	MOTOR S/N				NOMINAL @ 60° F
	PV16-521-5	PV16-521-10	PV16-532-6	PV16-532-7	
Average chamber pressure (psia)	1,758	1,815	1,731	1,669	1,710
Average burn rate (in/sec)	1.016	1.026	0.987	0.977	1.005
Burntime calculated (sec)	1.520	1.505	1.564	1.580	1.538*
Burntime measured (sec)	1.480	1.350	1.580	1.570	--
$\int_0^t P_c \, dt$** (psi-sec)	2,618	2,442	2,691	2,639	--

* Nominal burntime (PV16-521) = 1.531 sec

Nominal burntime (PV16-532) = 1.570 sec

** P_c = Chamber pressure

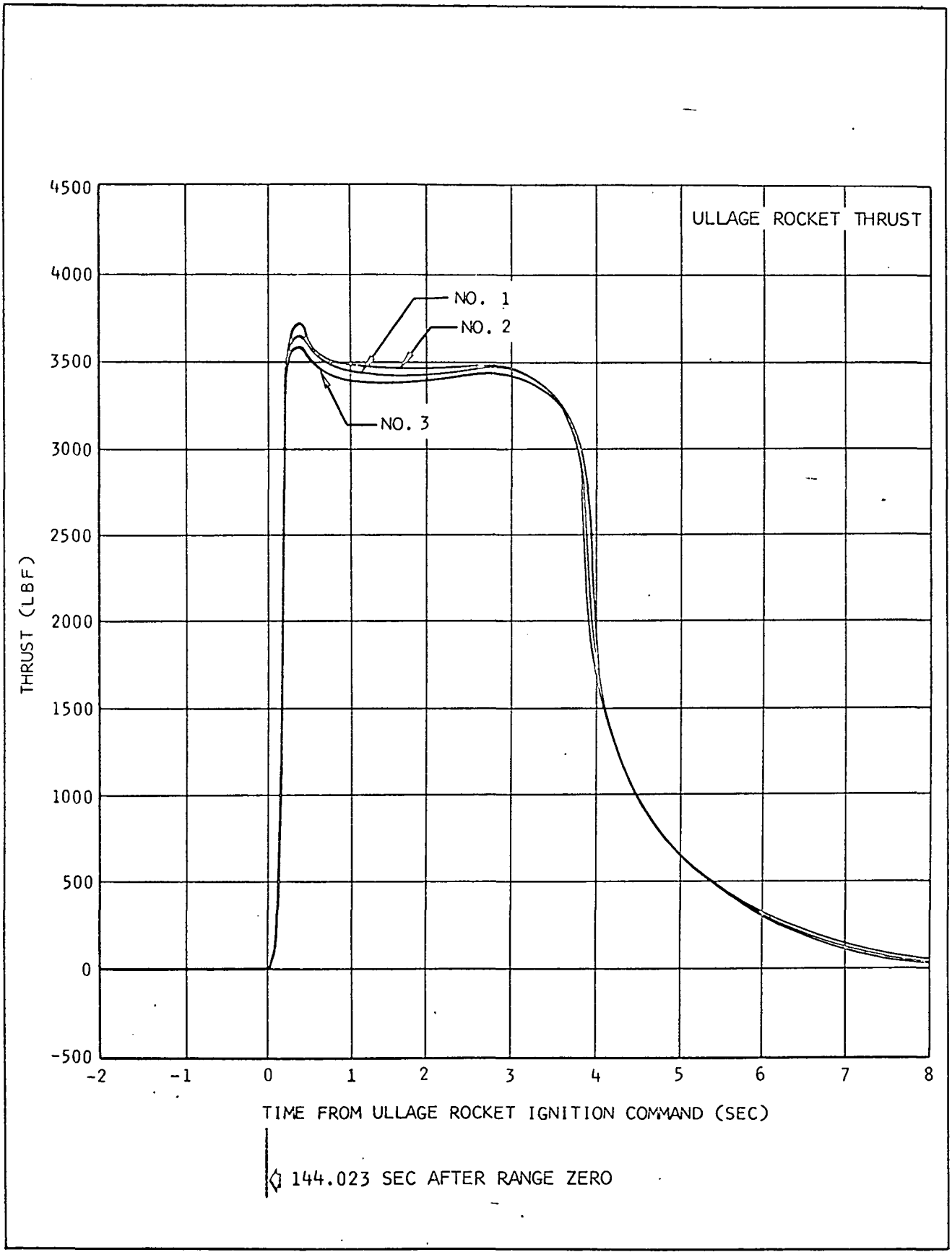

Figure 9-1. Ullage Rocket Performance

24 October 1966

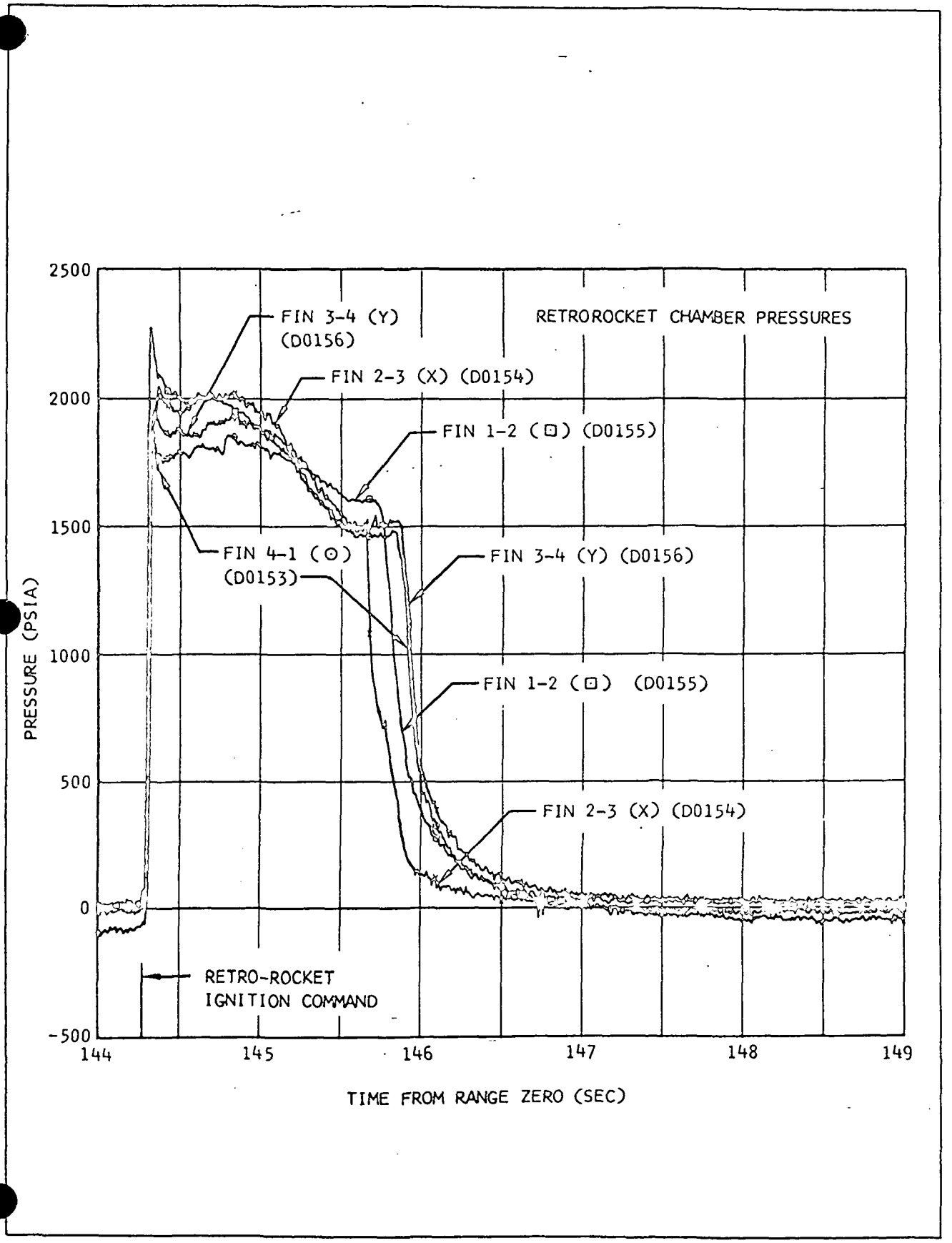

Figure 9-2. Retrorocket Performance

24 October 1966

10. OXIDIZER SYSTEM

The oxidizer system performed adequately throughout boost and powered flight. The LOX tank was satisfactorily prepressurized both before liftoff and during S-IB boost. Following engine start the ullage pressure was maintained within the prescribed control band. Cold helium supply and regulation were adequate. The recirculation chilldown system adequately chilled the LOX pump and ensured proper net positive suction head (NPSH) at engine start. The LOX supply to the engine during the firing period was satisfactory and the NPSH was maintained well above minimum limits.

10.1 Pressurization Control and Internal Environment

The LOX tank pressurization system (figure 10-1) satisfactorily maintained pressure in the LOX tank throughout the flight. All parts of the system performed close to their design specifications.

10.1.1 Prepressurization

LOX tank prepressurization was initiated 307 sec prior to engine start and increased the LOX tank ullage pressure from 16.4 psia to 40.5 psia within 15 sec (figure 10-2). One makeup cycle was required to maintain the LOX tank ullage pressure before the ullage temperature stabilized. The pressurization control pressure switch controlled the ullage pressure between 37.8 and 40.5 psia. After the makeup cycle, the ullage pressure gradually increased to 43.8 psia at ESC -179 sec as the LOX vent valve and LOX ullage pressure sensing lines were purged with ambient helium. At this time the LOX vent relief opened and the ullage pressure decreased to 42.9 psia and stabilized. The purge was terminated at liftoff as shown by the ullage pressure which started to decrease at this time, as the result of ullage cooling.

The ullage pressure continued to decrease until 7 sec prior to engine start. From this time to engine start, it increased from 38.7 to 41.0 psia as the stage decelerated and the liquid compressed the ullage. This phenomenon was also observed on the S-IVB-201 flight.

Prepressurization flowrates were calculated from temperature and pressure data obtained at the LOX vent inlet. Calculation showed that 3.8 lbm

of helium were used to prepressurize and maintain the LOX tank ullage pressure prior to Engine Start Command (ESC). Since the cold gas leaving the heat exchanger warmed to near-ambient temperature by the time it reached the LOX vent inlet, prepressurization was essentially accomplished with near-ambient temperature helium.

10.1.2 Pressurization

The LOX tank ullage pressure was 41.0 psia at engine start (figure 10-3). During engine firing, the LOX tank ullage pressure cycled within the control band seven times in 350 sec. After the last overcontrol cycle, the ullage pressure started its normal decrease and then began to stabilize. The ullage pressure cycled one more time than predicted because predictions were based on acceptance testing where the heat input to the LOX tank was larger. Except for a period immediately after engine start, the ullage pressure was maintained between 37.8 and 40.0 psia by the flight control pressure switch. This pressure control range agreed closely with the preflight pressure switch checks and predictions. After engine start, the pressure decreased rapidly to a minimum of 34.6 psia at ESC +22 sec, although the overcontrol valve had opened when the pressure was 37.7 psia. The pressure recovered after this transient and cycled normally. This situation is characteristic of the S-IVB stages. The decrease was a result of the low initial pressurant mass flowrate into the LOX tank caused by temperature transients at the bypass orifice and pressure transients at the heat exchanger outlet. As soon as the temperatures and pressures stabilized, the ullage pressure recovered and cycled satisfactorily. The pressure during this transient period was sufficient to meet the minimum NPSH requirements.

The LOX tank ullage temperatures show a stratified profile similar to, and within 10 deg R of, those which occurred during the S-IVB-201 flight and S-IVB-202 acceptance firing.

The LOX tank pressurization total flowrate varied from 0.39 to 0.45 lbm/sec during overcontrol, and from 0.26 to 0.33 lbm/sec during undercontrol. The variation in total flowrate was caused by a variation in the bypass flowrate. This variation is normal because the bypass orifice inlet temperature changes as it follows the cold helium sphere temperature.

The predicted total flowrates were 0.38 to 0.43 lbm/sec during overcontrol and 0.24 to 0.30 lbm/sec during undercontrol. The calculated collapse factor reached a maximum of 1.18 approximately 100 sec after engine start. It held fairly constant for 50 sec then decreased, reaching 1.14 at cutoff. The decrease in collapse factor toward the end of the firing was due to the pressurant entering the LOX tank at a temperature near the ullage temperature. When the temperature of the incoming gas is close to that of the ullage, the incoming pressurant experiences less collapse, and the collapse factor approaches the optimum value of 1.

10.1.3 LOX Tank Pressurization Control Module

The LOX tank pressurization module outlet temperature and pressure (figure 10-3) displayed normal profiles through the start transient and during engine operation. The temperature decreased to 165 deg R at ESC +17 sec and to 57 deg R at engine cutoff. Pressure varied, after stabilization, from 375 to 390 psia on overcontrol and 405 to 420 psia on undercontrol. The pressure was maintained within the specified 400 $\pm$25 psia during powered flight.

10.2 Cold Helium Supply

The cold helium spheres were loaded to 3,050 psia and 39.0 deg R at engine start (figure 10-4). By ESC +311 sec, the sphere pressure had decreased to a minimum of 1,090 psia; then, as the LH2 level fell below the spheres, the pressure slowly increased to 1,200 psia by engine cutoff. The sphere temperatures decreased normally, with the No. 5 (top) sphere decreasing to 33.6 deg R at approximately ESC +160 sec. The No. 1 sphere (lowest) reached a minimum of 28.8 deg R at ESC +225 sec, just before the lowest two spheres became uncovered. As each sphere became uncovered, it started the normal temperature increase, with the No. 5 sphere reaching 55.6 deg R while the lowest sphere reached only 48.4 deg R by engine cutoff. Cold helium sphere temperatures and pressure trends closely followed those predicted and those observed in the S-IVB-202 acceptance firing and S-IVB-201 flight.

Calculations using the cold helium sphere temperature and pressure conditions indicate that, at Engine Start Command, the spheres were loaded with 340 lbm of helium at 39 deg R and 3,050 psia. Helium consumption during the engine firing was approximately 153 lbm. A summation of the helium flowrates calculated from the control orifice temperature and pressure conditions also indicated a consumption of approximately 153 lbm.

10.3 J-2 Heat Exchanger

The J-2 heat exchanger inlet temperature began to decrease immediately after engine start as the line was being cooled. The temperature decrease was interrupted several times (figure 10-5) because of flowrate variations during undercontrol and overcontrol. The temperature reached a minimum of 35 deg R approximately 260 sec after engine start. Thereafter the temperature increased, reaching 57 deg R at engine cutoff. The heat exchanger inlet temperature showed the normal overcontrol and undercontrol temperature variations which have occurred during previous flights. The heat exchanger outlet temperature increased to 850 deg R during the 60-sec warmup transient. Throughout the initial high engine mixture ratio portion of the firing, the temperature varied between 875 and 935 deg R on overcontrol and 870 to 880 deg R on undercontrol. Temperatures during the flight were 25 to 50 deg R higher than those recorded during acceptance firing. This difference was caused by the absence of convective heat transfer loss in the uninsulated part of the pressurization line and by differences between the flight and acceptance test gas generator mixture ratio.

The heat exchanger outlet pressure followed the same profile as the pressurization module outlet pressure, varying between 340 and 355 psia while on overcontrol. During undercontrol, the outlet pressure increased from 400 psia on the first cycle to 410 psia after the last overcontrol cycle. The flow through the heat exchanger was relatively constant at 0.20 lbm/sec during overcontrol and 0.075 lbm/sec during undercontrol.

The LOX tank vent inlet pressure reflected the overcontrol and undercontrol operation and averaged 68 psia during overcontrol and 48 psia during undercontrol. The maximum LOX tank vent inlet temperature of 475 deg R was below the redline value of 560 deg R. Figure 10-5 shows a comparison of the LOX tank inlet temperature and the theoretical gas mixture temperature. The theoretical mixture temperature is the temperature that would be obtained by complete mixing of the cold bypass gas and the hot gas from the J-2 engine heat exchanger. This comparison gives an indication of the heat transfer to or from the pressurization lines between the mixing point and the vent inlet. It also shows that the system stabilized only after an extended period of overcontrol or undercontrol operation.

The LOX tank diffuser temperature cycle was similar to that of the LOX vent inlet temperature. A maximum temperature of 379 deg R occurred during overcontrol; the minimum, 226 deg R, occurred during undercontrol. Figure 10-5 also shows the heat lost by the pressurant helium to the LOX bulk during firing. The heat loss was greater during overcontrol than undercontrol and decreased as the liquid level decreased.

10.4 LOX Chilldown

The LOX pump chilldown system performed adequately. At Engine Start Command the pump inlet conditions were 41.0 psia and 165.0 deg R, providing an available NPSH of 24.5 psi, well above the minimum acceptable value of 16.7 psi.

Recirculation chilldown was started at RO -872 sec and was terminated shortly before engine start. To remove any bubbles which might have collected under it during chilldown, the prevalve was commanded open at ESC -3 sec while the chilldown pump was still running. The chilldown shutoff valve was closed immediately before engine start.

After prepressurization, the ullage pressure varied with the normal makeup cycles until liftoff. During this time interval, the turbopump inlet pressure and return line pressure followed the ullage pressure trend. After liftoff the ullage pressure decreased, while the chilldown system pressures increased rapidly as a result of the increasing vehicle

acceleration. At approximately ESC -4 sec the S-IB inboard engines were cut off causing the turbopump inlet pressure and return line pressure to decrease (figure 10-6). These pressures decreased further at S-IB outboard engine cutoff (ESC -3 sec). Opening of the prevalve at approximately the same time caused a loss of chilldown pump developed head and additional pressure decrease. The turbopump inlet pressure increased beyond 60 psia at 20 sec after liftoff thus exceeding the range of the transducer. Thereafter the turbopump inlet pressure was estimated by adding the chilldown pump developed head and liquid head pressures (determined from predicted vehicle acceleration data) to the ullage pressure (figure 10-7). As the turbopump inlet pressure increased during boost it also diverged from the return line pressure because the pump inlet transducer was located approximately 69 in. lower than the return line pressure transducer and was subjected to a larger liquid head which increased with acceleration.

During the chilldown process the LOX was subcooled throughout the recirculation system resulting in 17.0 deg R of subcooling at the pump inlet at Engine Start Command. The chilldown flowrate was 44.3 gpm, and the frictional pressure drop through the system was 7.0 psi. The flow coefficient, a measure of the flow resistance, was 10.0 $sec^2/in^2\ ft^3$ (figure 10-6). This value is nearly equal to that obtained from S-IVB-202 acceptance firing data, thus demonstrating the consistency of the data since the flow coefficient is only a function of hardware geometry.

The NPSH at the turbopump inlet reached 41.1 psi at liftoff, after which time it increased with increasing pump inlet pressure to a maximum value of 62.0 psi at S-IB inboard engine cutoff. After this time it dropped continuously to a value of 24.8 psi at S-IVB Engine Start Command.

The chilldown system temperatures increased slightly prior to liftoff as a result of bulk heating. After liftoff, the chilldown system temperature increased slightly during the first few seconds of boost, then decreased during the remaining period of boost. By engine start, the heat inputs had gradually decreased to the levels presented in figure 10-6.

These same heating trends were observed during S-IVB-201 and 203 flights. The heat input rates before liftoff and at engine start were as follows:

	Heat Input (Btu/hr)	
	Before Liftoff	Engine Start
Section 1 (tank to pump inlet)	3,500	1,000
Section 2 (pump inlet to bleed valve)	22,000	12,000
Section 3 (bleed valve to tank inlet)	4,500	0
Entire chilldown system	30,000	13,000

10.5 Engine LOX Supply

The engine LOX supply system (figure 10-8) provided LOX to the engine within specifications throughout the engine firing period. The minimum available NPSH during engine operation was 21.1 psi, which occurred at ESC +20 sec. The allowable minimum NPSH at that time was 20.4 psi.

The LOX pump inlet static pressure was 42.0 psia at engine start (figure 10-9). It then cycled with the ullage pressure, reaching a minimum of 34.9 psia at ESC +20 sec. The pump inlet static pressure agreed closely with predicted values; however, one more cycle occurred than was predicted (paragraph 10.1.2).

The pump inlet temperature was 165.1 deg R at engine start. It decreased to 164.6 deg R when the LOX from the tank replaced the slightly warmer LOX in the suction duct and then increased with time during engine operation, reaching 165.8 deg R at engine cutoff. The pump inlet temperature was continuously about 0.7 deg R above the predicted value. This temperature was caused by data accuracy tolerances and by a higher-than-predicted vent system back pressure which caused a higher-than-predicted saturation temperature prior to liftoff. LOX pump inlet pressures and temperatures during engine operation are shown in figure 10-10, which shows that the engine LOX pump inlet conditions were met satisfactorily throughout engine operation.

The available NPSH at the LOX pump inlet was 24.8 psi at engine start. It increased to a maximum of 26.8 psi at ESC +3 sec. Since the pump inlet temperature varied only 0.4 deg R durikng the first 350 sec of engine operation, the NPSH varied almost directly with the ullage pressure. At engine cutoff the NPSH was approximately 23.5 psi. The NPSH in general was slightly less than predicted (approximately 1 psi), but was greater than required.

The average frictional pressure drop in the LOX suction duct was 3.1 psi during high engine mixture ratio (EMR) operation at an average LOX flowrate of 448 lbm/sec. This compares favorably with the acceptance firing pressure drop of 2.54 psi at a flowrate of 443 lbm/sec. After EMR cutback the pressure drop calculations became inaccurate due to the effects of the rapidly increasing acceleration on the pressure head. The flowrate of 356 lbm/sec would indicate a pressure of approximately 2.0 psi based on acceptance firing results.

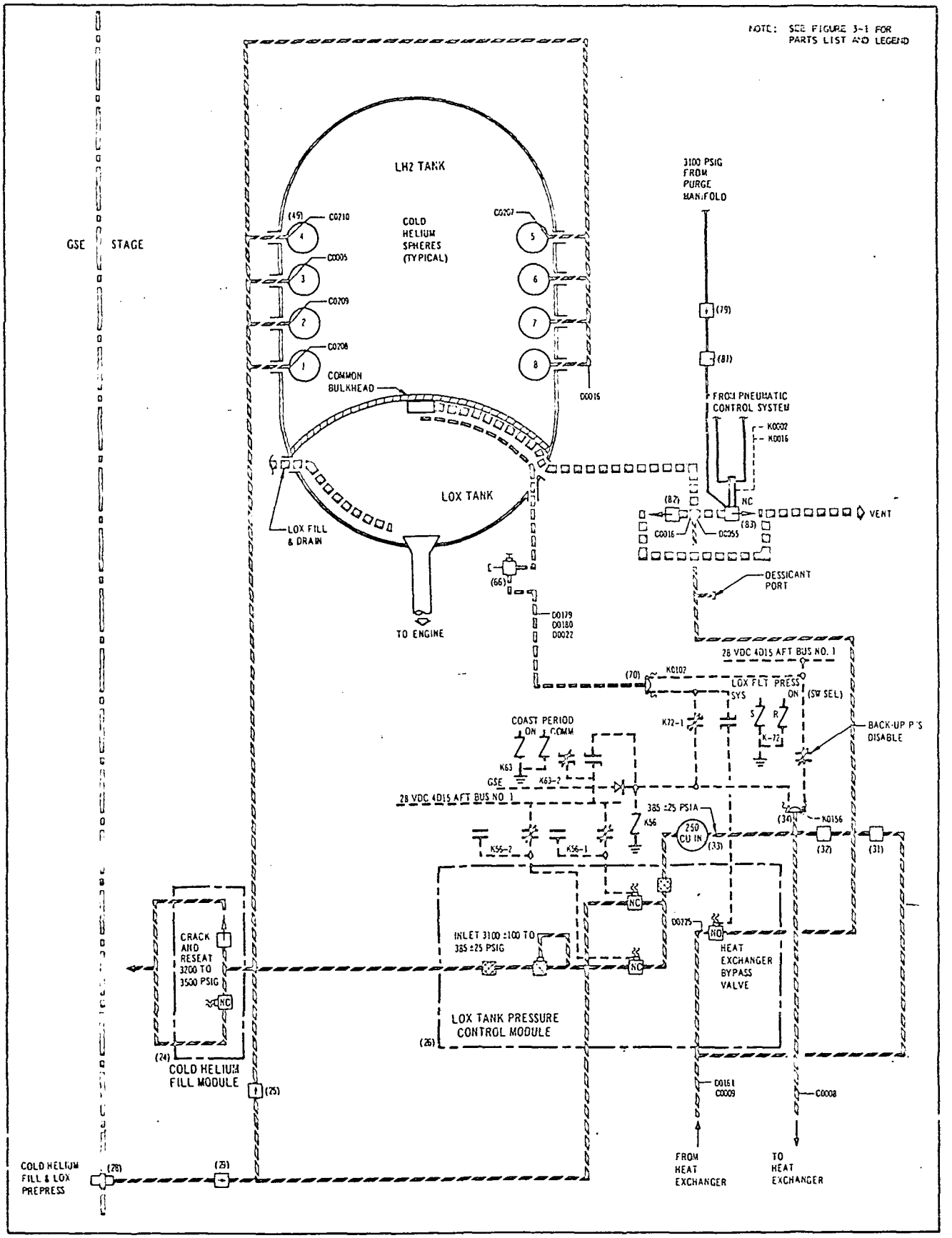

Figure 10-1. LOX Tank Pressurization System

24 October 1966

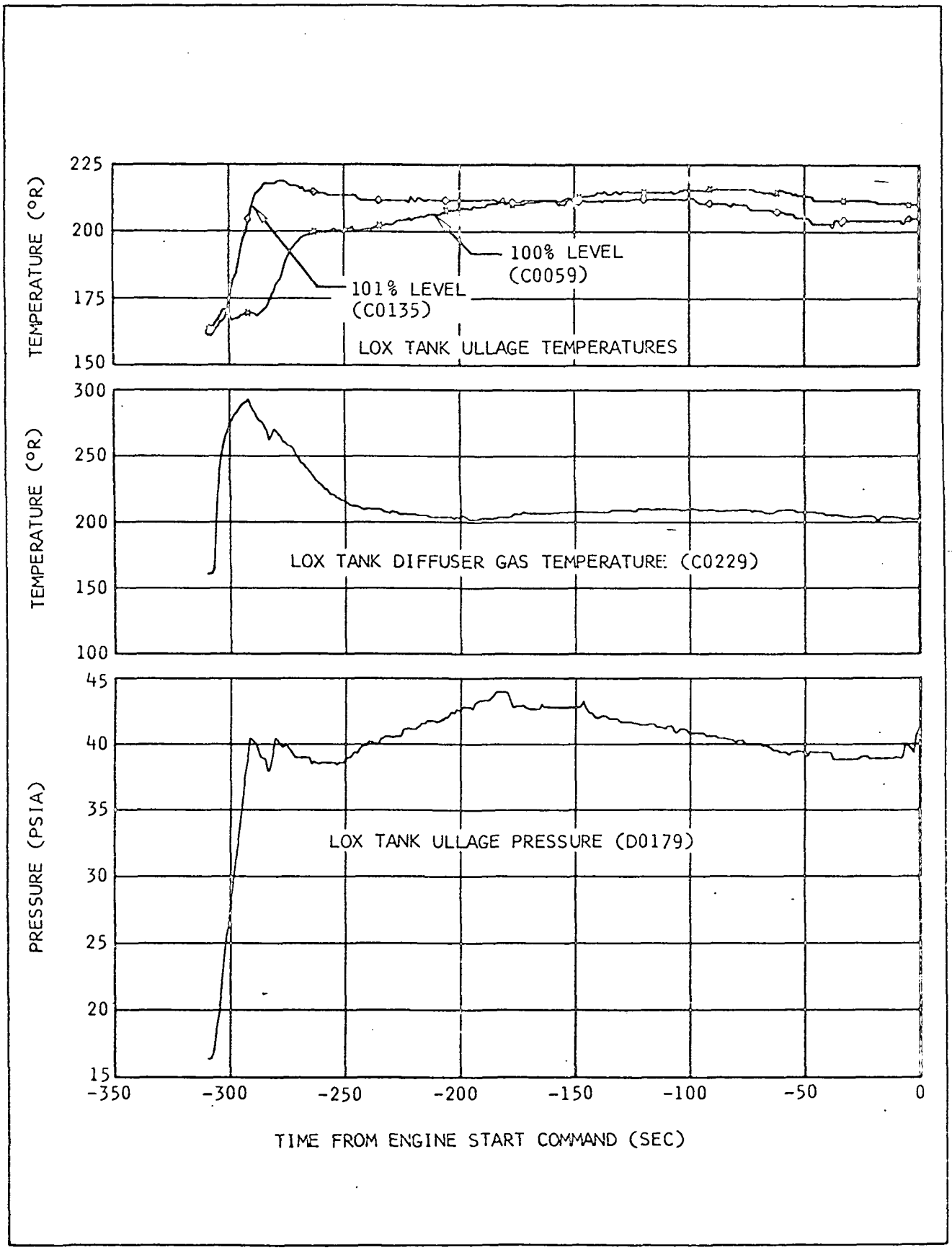

Figure 10-2. LOX Tank Conditions During Prepressurization and Boost

24 October 1966

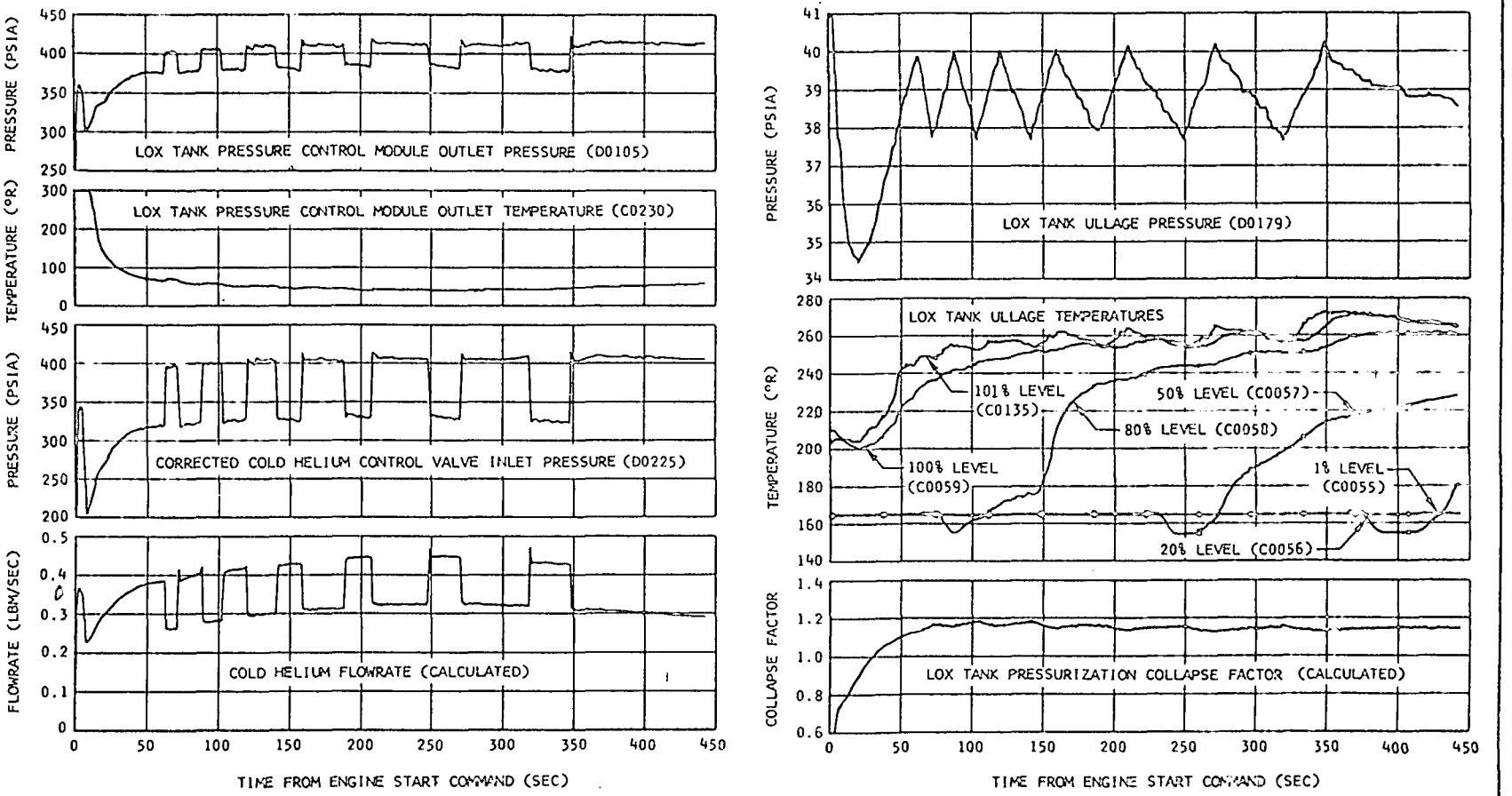

Figure 10-3. LOX Tank Pressurization System Performance

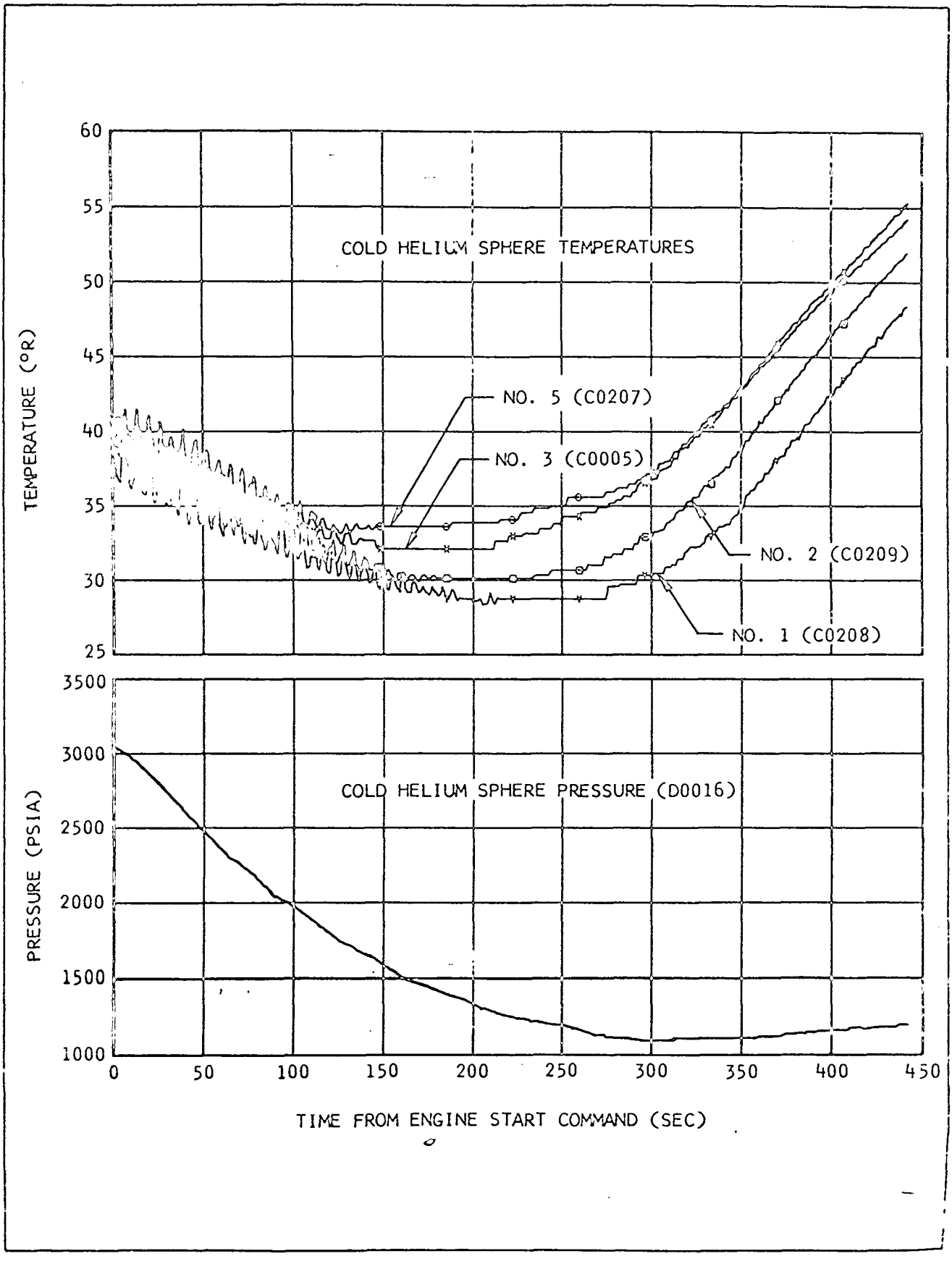

Figure 10-4. Cold Helium Supply

24 October 1966

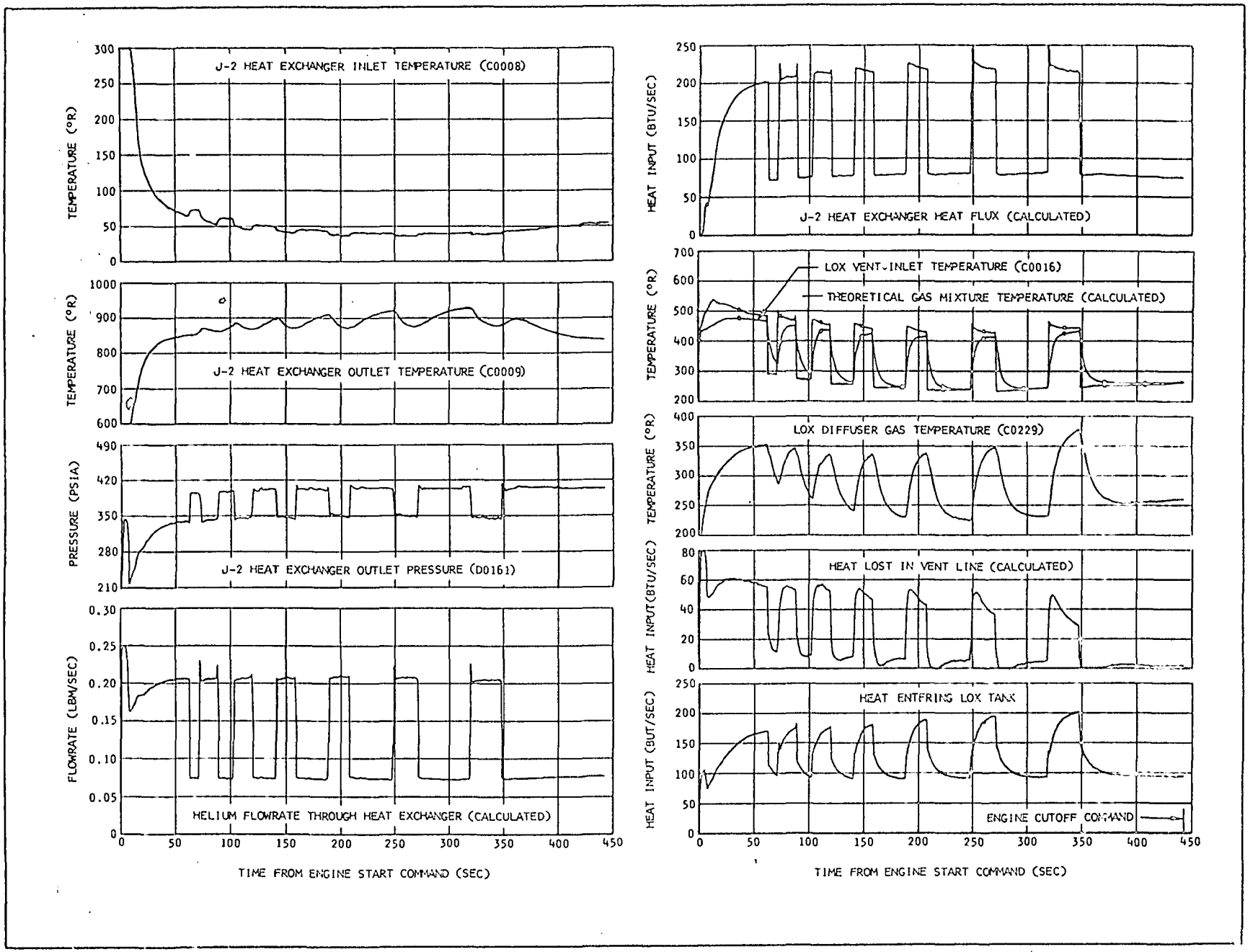

Figure 10-5. J-2 Heat Exchanger Performance

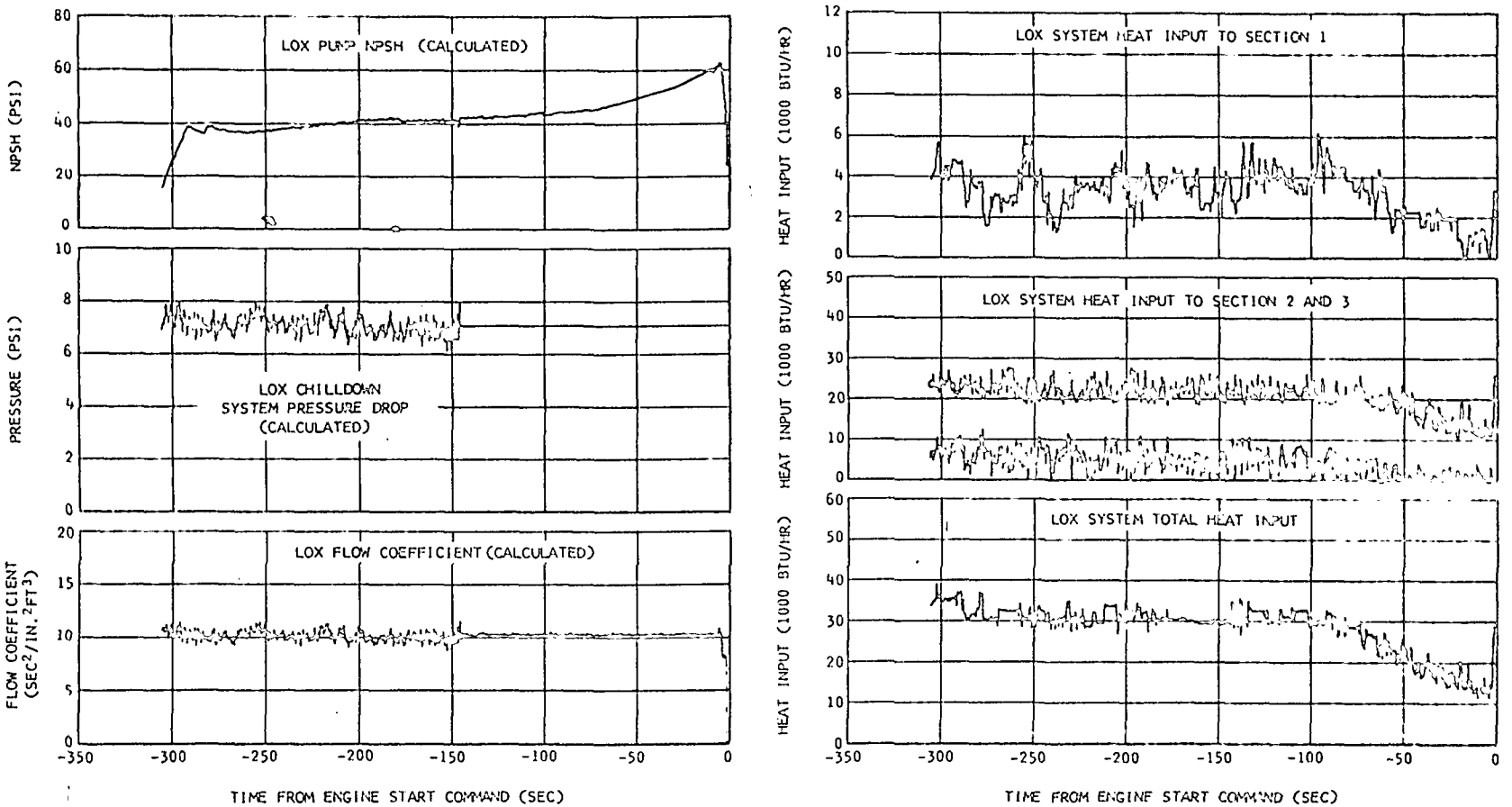

Figure 10-6. LOX Pump Chilldown System Performance

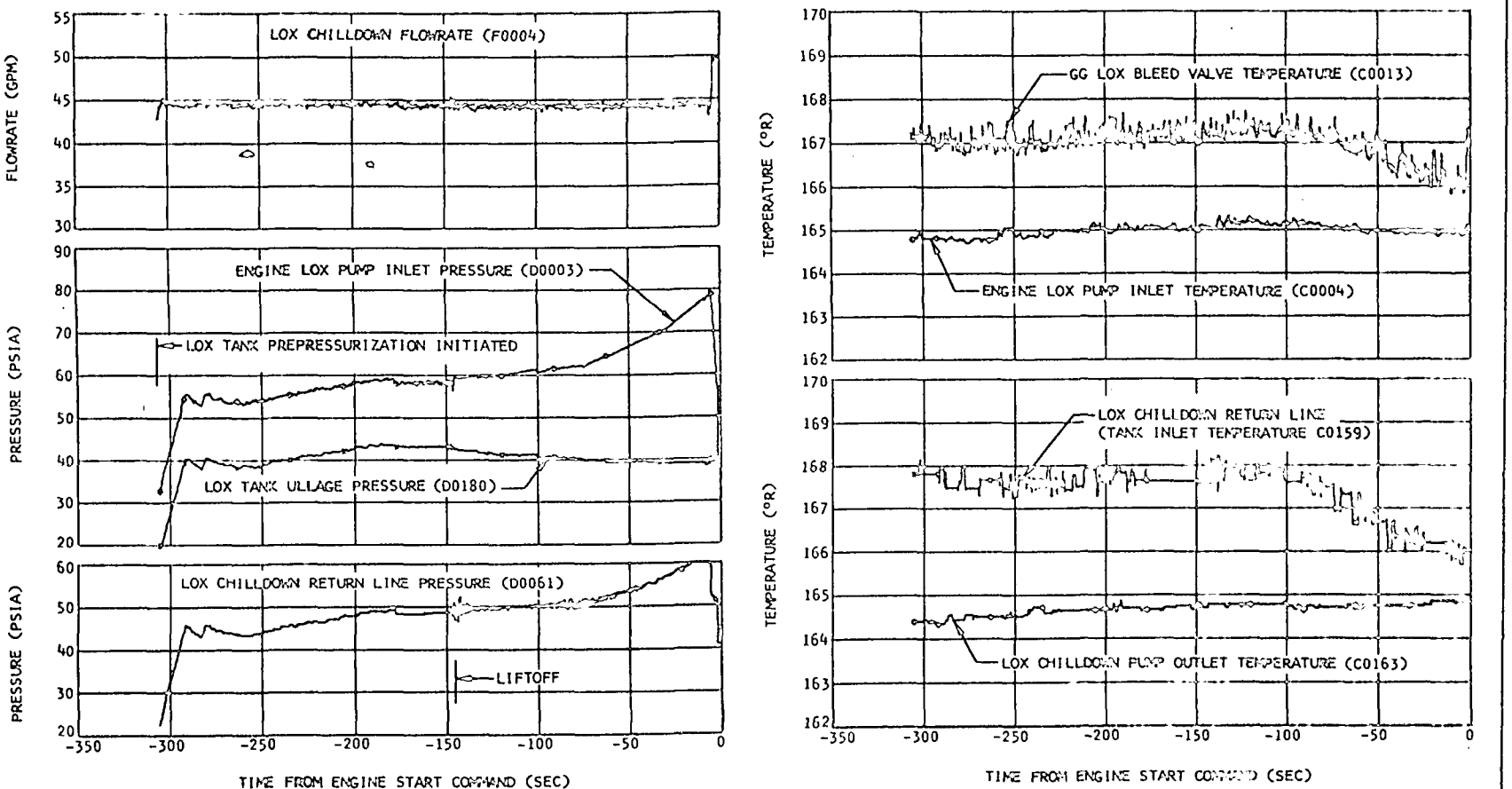

Figure 10-7. LOX Pump Chilldown System Operation

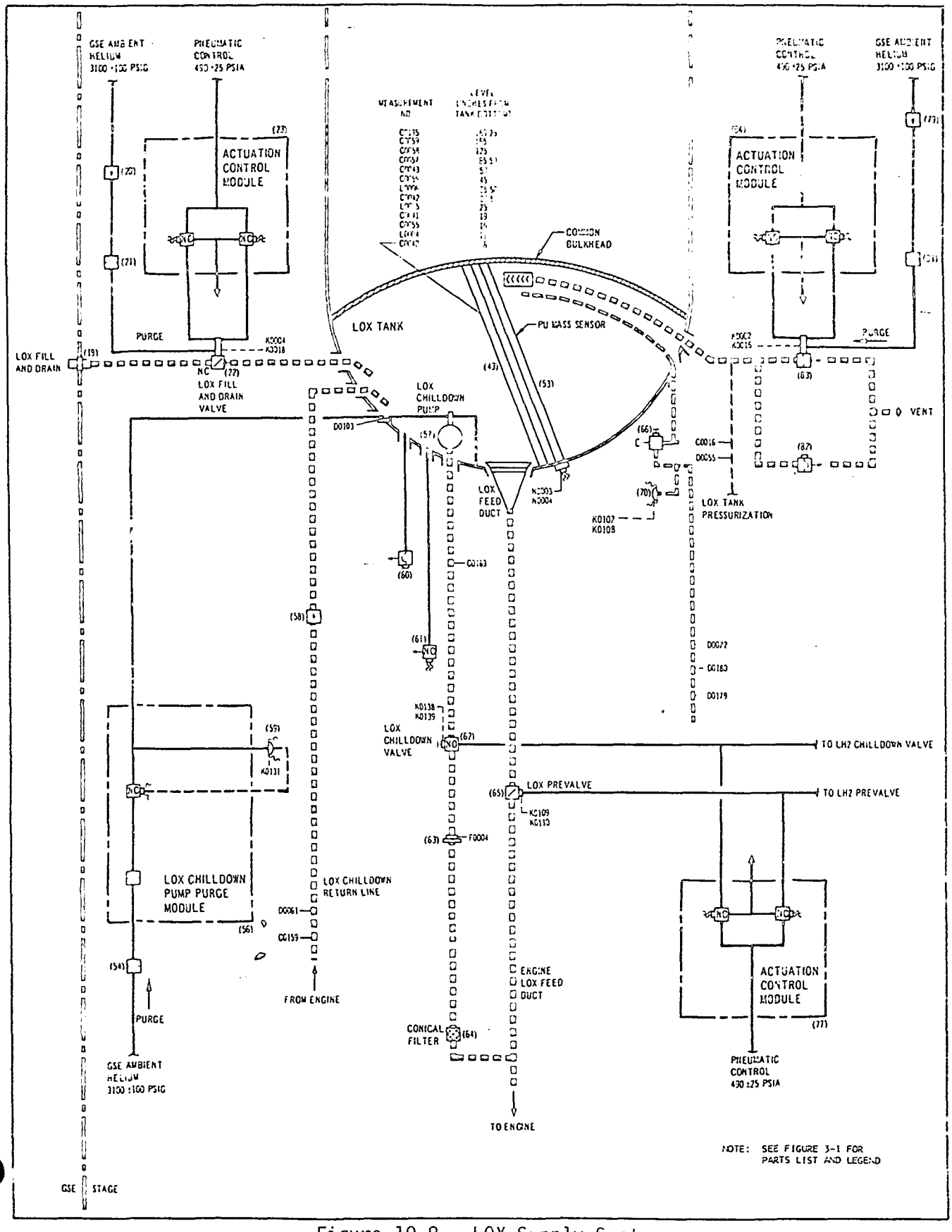

Figure 10-8. LOX Supply System

24 October 1966

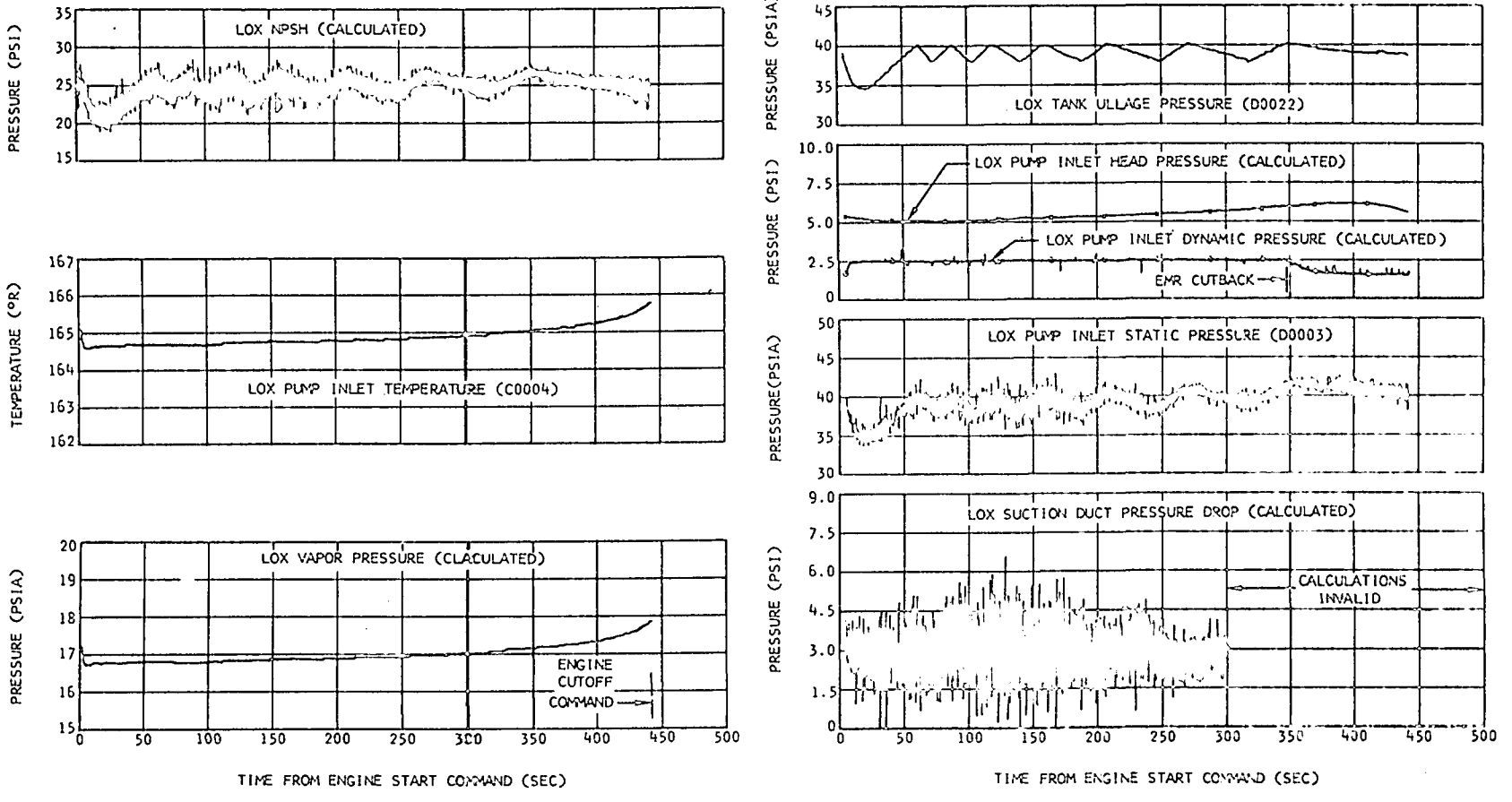

Figure 10-9. LOX Pump Inlet Conditions

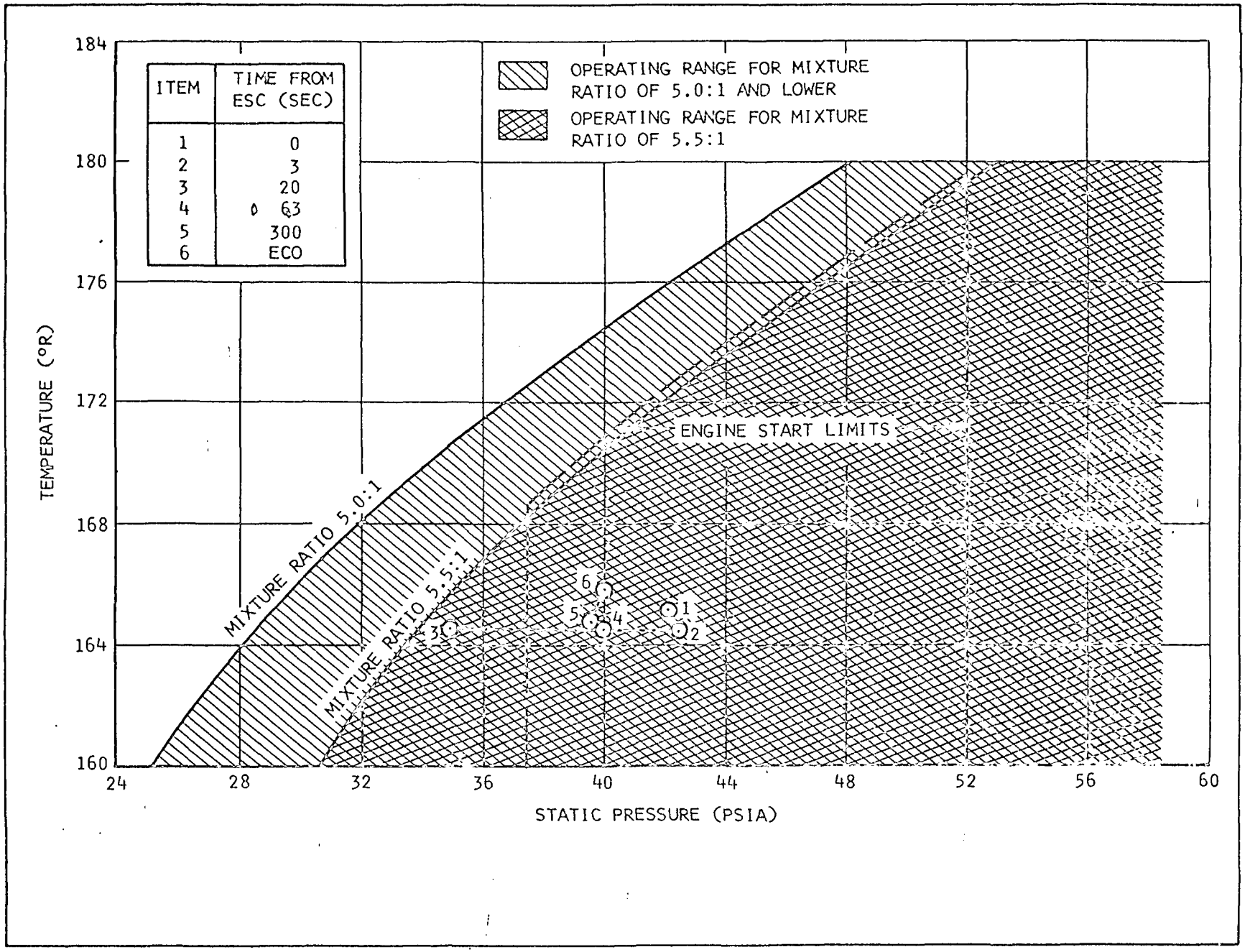

Figure 10-10. LOX Pump Inlet Conditions During Firing

11. FUEL SYSTEM

The fuel system performed as designed and supplied LH2 to the engine within the limits defined in the engine specification.

11.1 Pressurization Control and Internal Environment

The LH2 tank pressurization system (figure 11-1) operated in three phases: prepressurization, primary pressurization, and step pressurization, and satisfactorily controlled the LH2 tank ullage pressure for the duration of the firing.

11.1.1 Prepressurization

The LH2 tank conditions prior to prepressurization were 37.0 deg R and 15.8 psia, with the LH2 bulk being saturated. The LH2 prepressurization command was received at range zero (RO) -110 sec and the LH2 tank pressurized signal was received 67 sec later when the LH2 tank ullage pressure reached 36.9 psia. The ullage pressure continued to increase as the ullage volume warmed, reaching 37.7 psia at liftoff.

No prepressurization helium supply data were received from the launch site, but calculations based on ullage pressure and temperature data, derived with the aid of previous acceptance firing experience, indicate that approximately 35 lbm of helium were added to the ullage during prepressurization. Conditions from prepressurization to Engine Start Command (ESC) are summarized in figure 11-2.

The LH2 tank ullage pressure continued to increase after liftoff and reached 41 psia by Engine Start Command.

11.1.2 Pressurization

The LH2 tank internal conditions are shown in figure 11-3. Between Engine Start Command and ESC +2.8 sec, the GH2 bleed from the engine flowed into the LH2 tank through the normal pressurization orifice, the control pressurization orifice, and the step pressurization orifice.

The control and step pressurization valves are normally open at Engine Start Command and are closed at ESC +2.8 sec. Therefore, a momentary

high flow of GH2 entered the LH2 tank at engine start. This, however, produced no noticeable increase in ullage pressure at engine start.

When the control and step pressurization valves were closed, the ullage pressure began a normal decrease to a minimum of 28.8 psia at ESC +142 sec. The predicted ullage pressure decay time to this value was approximately 160 sec. Considering that the initial ullage pressure was slightly higher than predicted, this was in fair agreement with that actually attained.

There was a significant difference between the ullage pressure characteristics of the S-IVB-202 and 201 stages. The ullage collapse and boiloff during the S-IVB-201 flight were higher than during the S-IVB-202 flight. This difference was primarily the result of a pressurant diffuser modification. The S-IVB-202 diffuser was surrounded by a perforated nylon bag to prevent turbulence resulting from injection of pressurant streams into the ullage, and to effect a more uniform distribution of the pressurant. The effectiveness of this modification is evident in the ullage temperature data which indicate a stratified ullage (figure 11-3). This stratified ullage presents a warmer layer of gas to the incoming pressurant, reducing collapse, and a colder layer of gas to the liquid surface, inhibiting boiloff (paragraph 11.4).

The S-IVB-202 performance is in sharp contrast to the S-IVB-201 flight (without the modification) which exhibited considerable ullage mixing. The average ullage temperature was 80 to 90 deg colder on S-IVB-201 with resultant high collapse and boiloff. It should be noted, however, that the S-IVB-201 stage had a much higher slosh level than S-IVB-202 which contributed to a higher collapse and boiloff level and tends to exaggerate the effectiveness of the modification in this comparison. Data from the S-IVB-203 flight, nevertheless, tend to confirm these observations. The overall result of the modification was a much more efficient usage of the pressurizing gas.

In the transient conditions during the first 20 to 30 sec of engine firing, the LH2 tank pressurization module and the LH2 tank inlet temperatures decreased very rapidly to steady-state values. The injector

temperature, however, increased to its steady-state value because fuel lead had chilled the injector to a low temperature immediately prior to ignition (figure 11-3). The GH2 tapoff pressure and temperature measurements exhibited normal profiles. The GH2 tapoff port pressure (the source of the LH2 tank pressurization gas) was constant at about 875 psia until ESC +290 sec, then decreased to 850 psia because of engine mixture ratio changes. Step pressurization was automatically initiated at ESC +300 sec to provide adequate fuel pump NPSH until engine cutoff. The ullage pressure increased from 29.0 psia to 41.2 psia at engine cutoff during this period. All pressurization system parameter operating levels were consistent with data obtained from the S-IVB-201 flight, although the engine appeared to operate much steadier and produced a much lower degree of pressurization system temperature and pressure fluctuations.

The LH2 tank inlet pressure indicated the usual difference between modes of system operation. The inlet pressure was about 40 psia during undercontrol pressurization, 50 psia during control pressurization, and 93 to 100 psia during step pressurization. These levels were reasonably consistent with the S-IVB-202 acceptance firing data at comparable pressurization flowrates. The GH2 pressurization flowrates obtained were very near predictions. From engine start to engine cutoff, 281 lbm GH2 were added to the ullage as compared to a predicted total flow of approximately 305 lbm. The collapse factor varied from 0.6 to 0.75 during steady-state operation of the pressurization system.

11.2 LH2 Chilldown

The LH2 chilldown system performed satisfactorily. At Engine Start Command the pump inlet pressure and temperature were 41.0 psia and 38.2 deg R respectively, indicating 5.5 deg R of subcooling. The NPSH at Engine Start Command was 21.8 psi, well above the minimum requirement of 8.5 psi. System temperature, pressures and flowrate, are presented in figures 11-4 and 11-5.

Chilldown was initiated at RO -869 sec. During unpressurized chilldown, saturated conditions existed throughout the chilldown system. A fuel

quality of 0.06 lbm gas/lbm mixture was observed during this time. The chilldown pump developed a pressure head of 6.7 psi and the flowrate stabilized at 89.0 gpm before LH2 tank prepressurization. LH2 tank prepressurization was initiated at RO -110 sec. The chilldown flowrate increased off-scale high, during prepressurization, as vapor was forced out of the system and replaced by liquid from the tank. The liquid entering the system was sufficiently subcooled after pressurization to absorb all the heat input from the system without vaporizing. Pump inlet, bleed valve, and return line temperature increased at the initiation of prepressurization as a result of the increased saturation temperature. These temperature increases followed the saturation curve until the LH2 entering the system became sufficiently subcooled to absorb the heat input of the system from the tank to the respective transducer location without reaching saturation temperature.

When steady-state conditions were achieved after prepressurization, subcooled liquid existed throughout the chilldown system.

After liftoff, all chilldown system temperatures decreased until engine start. The pump inlet temperature was 39.5 deg R at liftoff and decreased to a normal 38.2 deg R at engine start. This decrease was greater than observed on the S-IVB-201 and 203 flights because the heat input rate and resulting temperature in the system between the tank and the LH2 pump inlet, prior to liftoff, was higher for the S-IVB-202 flight.

During pressurized chilldown prior to liftoff, the NPSH was 21.0 psi. As the acceleration head increased and the system temperatures decreased, during boost, the NPSH increased to a maximum of 31.5 psi just prior to booster inboard engine cutoff. At S-IVB engine start the NPSH was 21.8 psi, which was well above the minimum requirement of 8.5 psi. Heat leakage into the fuel chilldown system is shown in figure 11-5 and is compared with the corresponding preliftoff data from S-IVB-201 and 203 flights in the following table.

	AVERAGE PRELIFTOFF HEAT INPUT (BTU/HR)					
	UNPRESSURIZED			PRESSURIZED		
STAGE	201	203	202	201	203	202
Section 1 (Tank to pump inlet)	22,000	25,000	24,000	22,000	30,000	31,000
Section 2 (Pump inlet to bleed valve)	Not possible to individually Calculate			14,000	3,000	6,000
Section 3 (Bleed valve to tank return)				4,000	24,000	17,000
Sections 2 + 3	24,000	16,000	40,000	18,000	27,000	23,000
Entire chilldown system	46,000	41,000	64,000	40,000	57,000	54,000

During boost, the bleed valve and return line temperatures decreased due to decreasing heat inputs. Just prior to engine start, the total heat input rate to the system was approximately 21,800 Btu/hr.

The system flow coefficient, calculated from flowrate and pressure drop data, was approximately 10.8 $sec^2/in^2\ ft^3$ as compared with 12.0 $sec^2/in^2\ ft^3$ on the S-IVB-202 acceptance firing.

The LH2 recirculation shutoff valve was commanded closed just prior to Engine Start Command; however, it did not fully close (paragraph 11.5).

11.3 Engine LH2 Supply

The J-2 engine LH2 supply system provided LH2 to the engine within specifications throughout the engine firing period (figure 11-6). The minimum available NPSH during engine operation was 7.3 psi which occurred at ESC +297 sec. The allowable minimum NPSH at that time was 5.4 psi. The adequacy of the LH2 supply was not affected by the failure of the LH2 recirculation shutoff valve to close.

The LH2 pump inlet static pressure was 40.9 psia at engine start (figure 11-7). It then followed the ullage pressure, reaching a minimum of

26.5 psia at ESC +135 sec. The pump inlet static pressure agreed closely with predicted values.

The LH2 pump inlet temperature was 38.1 deg R at engine start. It decreased to 37.8 deg R after the start transient and then increased with time during engine operation, reaching 40.1 deg R at engine cutoff. The pump inlet temperature indication remained approximately 0.4 deg R above the predicted value. The temperature data, however, indicated 0.4 deg R high under saturated conditions prior to prepressurization. Fuel pump inlet pressure and temperature conditions were satisfactorily met throughout engine operation (figure 11-8).

The available NPSH at the fuel pump inlet was 21.8 psi at engine start. It increased to a maximum of 22.0 psi at ESC +3 sec, when the LH2 in the tank replaced the slightly warmer LH2 in the suction duct. Since the pump inlet temperature varied only 0.8 deg R during the first 300 sec of engine burn, the NPSH varied almost directly with the ullage pressure. After step pressurization was initiated at ESC +300 sec, the NPSH increased with the ullage pressure to 15.0 psi at engine cutoff. The NPSH agreed very closely with predictions.

The average frictional pressure drop in the LH2 suction duct during high engine mixture ratio (EMR) operation was 1.7 psi at an average flowrate of 79 lbm/sec. After EMR cutback the pressure drop calculations became inaccurate due to the effect of the rapidly increasing accelerations. The average flowrate after EMR cutback was 72 lbm/sec, which would indicate a pressure drop of approximately 1.3 psi.

11.4 LH2 Boiloff

Calculations based on LH2 tank ullage pressure and temperature conditions at engine start and cutoff indicate no fuel boiloff during J-2 engine firing. This was as predicted. The boiloff was minimized by a modification to the pressurization diffuser (paragraph 11.1.2).

11.5 Recirculation Shutoff Valve Anomaly

The fuel recirculation shutoff valve failed to close as commanded before Engine Start Command. The same failure occurred on the S-IVB-203 flight. It appears that solid air or nitrogen may have formed in the outer convolutions of the outer bellows, thus preventing the bellows from compressing more than a small distance. The shutoff valve "open" position signal dropped out as expected before Engine Start Command, indicating that the poppet had moved a fraction of its normal travel. The closed indication, however, was not received. A fuel recirculation flowrate of 60 to 70 gpm and a recirculation pump outlet temperature of 37 to 39 deg R after engine start, confirmed the indication that the shutoff valve did not close.

The actuation control module for the valve is normally closed. In this position the vent port in the module is open to the atmosphere (interstage). Liquid hydrogen in the recirculation valve is free to flow inside the outer bellows which would cause any helium in the actuator space to collapse and air or nitrogen to condense. As a result more air or nitrogen could be cryopumped through the vent port until equilibrium is reached.

After liftoff the pressure at the vent port decreased as the interstage pressure decreased with altitude. This pressure reduction could cause expansion flash-off and cooling of the liquid air or nitrogen, causing eventual freezing. Decreasing ambient heating of the valve would aid the solidification process.

It is reasonable that the valve might fail in flight after operating successfully during ground tests as a result of colder hydrogen temperatures and the vacuum in the valve vent system. However, it is difficult to understand why the valve would fail on the S-IVB-202 and 203 flights and perform successfully on the S-IVB-201 flight. Therefore, the valve will be tested under flight conditions to positively identify the failure mechanism.

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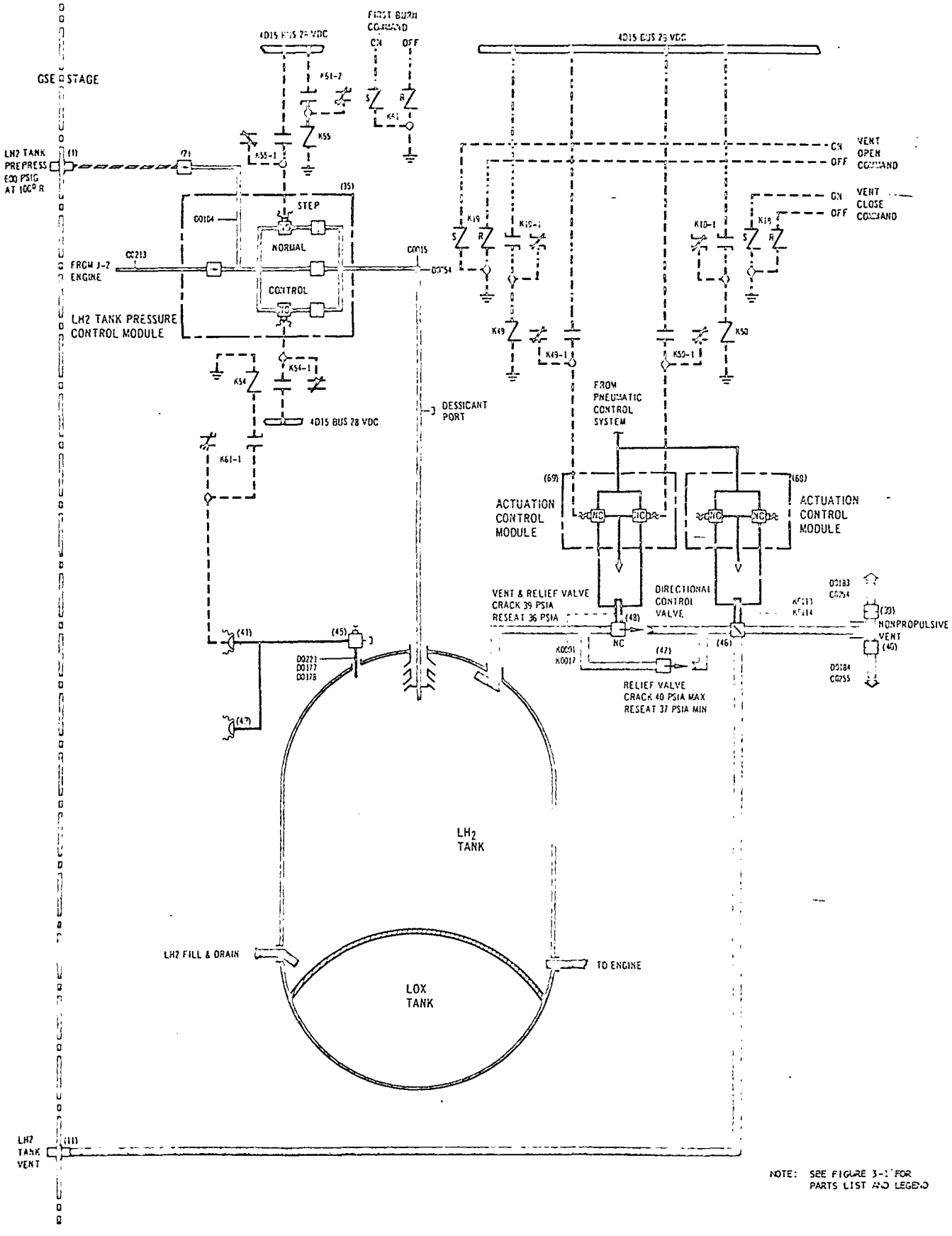

Figure 11-1. LH2 Tank Pressurization System

24 October 1966

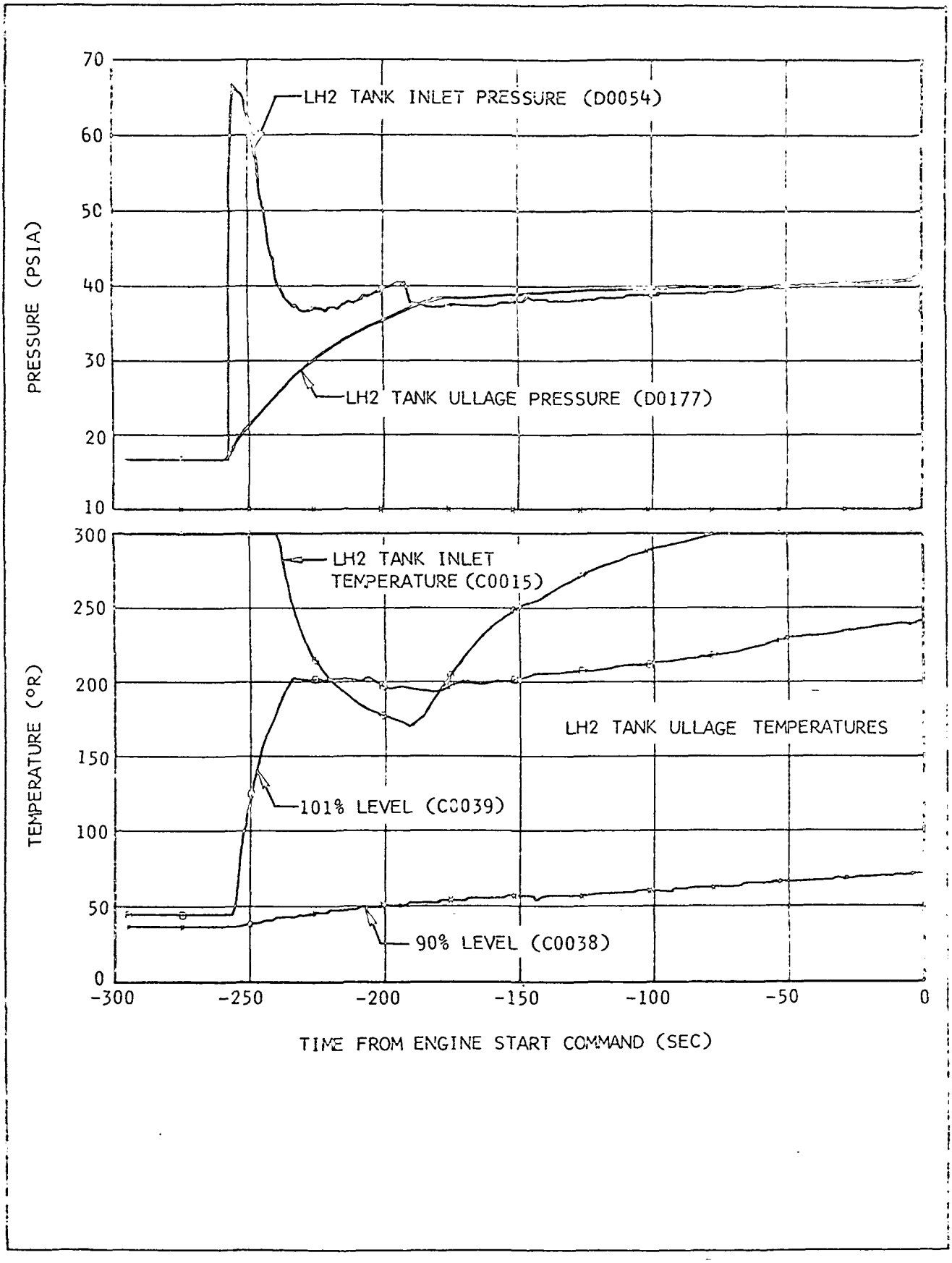

Figure 11-2. LH2 Tank Prepressurization System Performance

24 October 1966

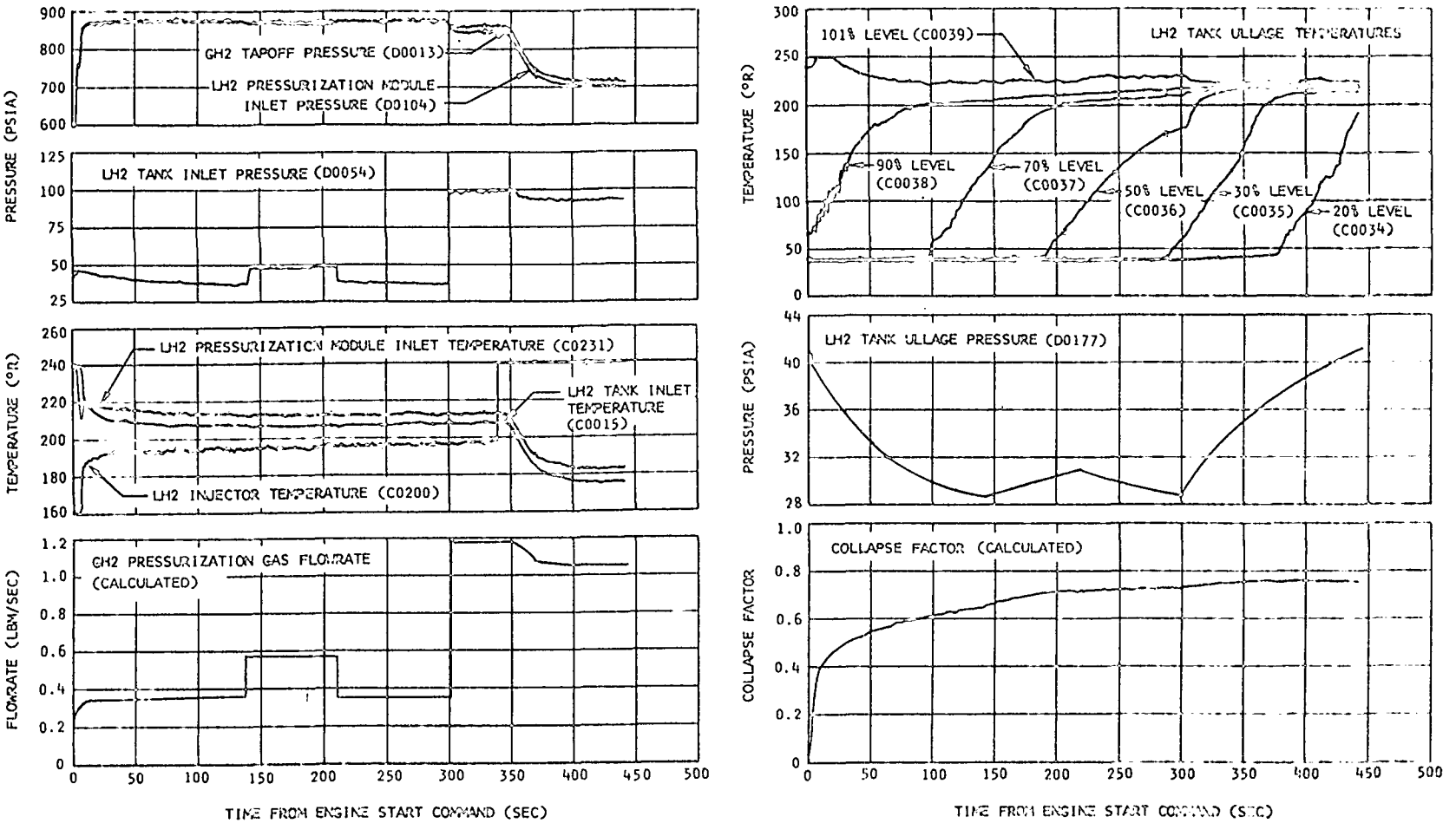

Figure 11-3. LH2 Tank Pressurization System Performance

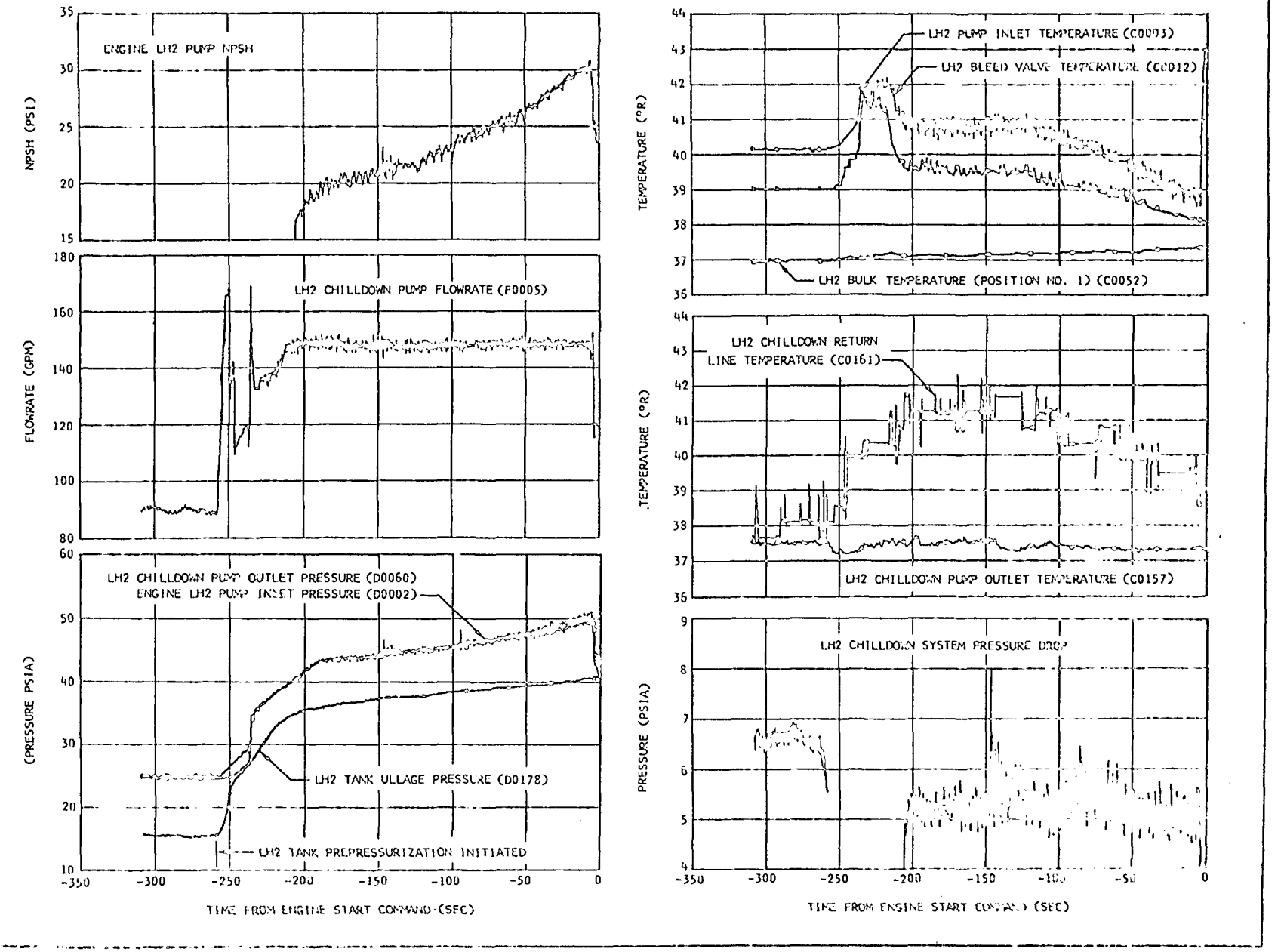

Figure 11-4. LH2 Pump Chilldown

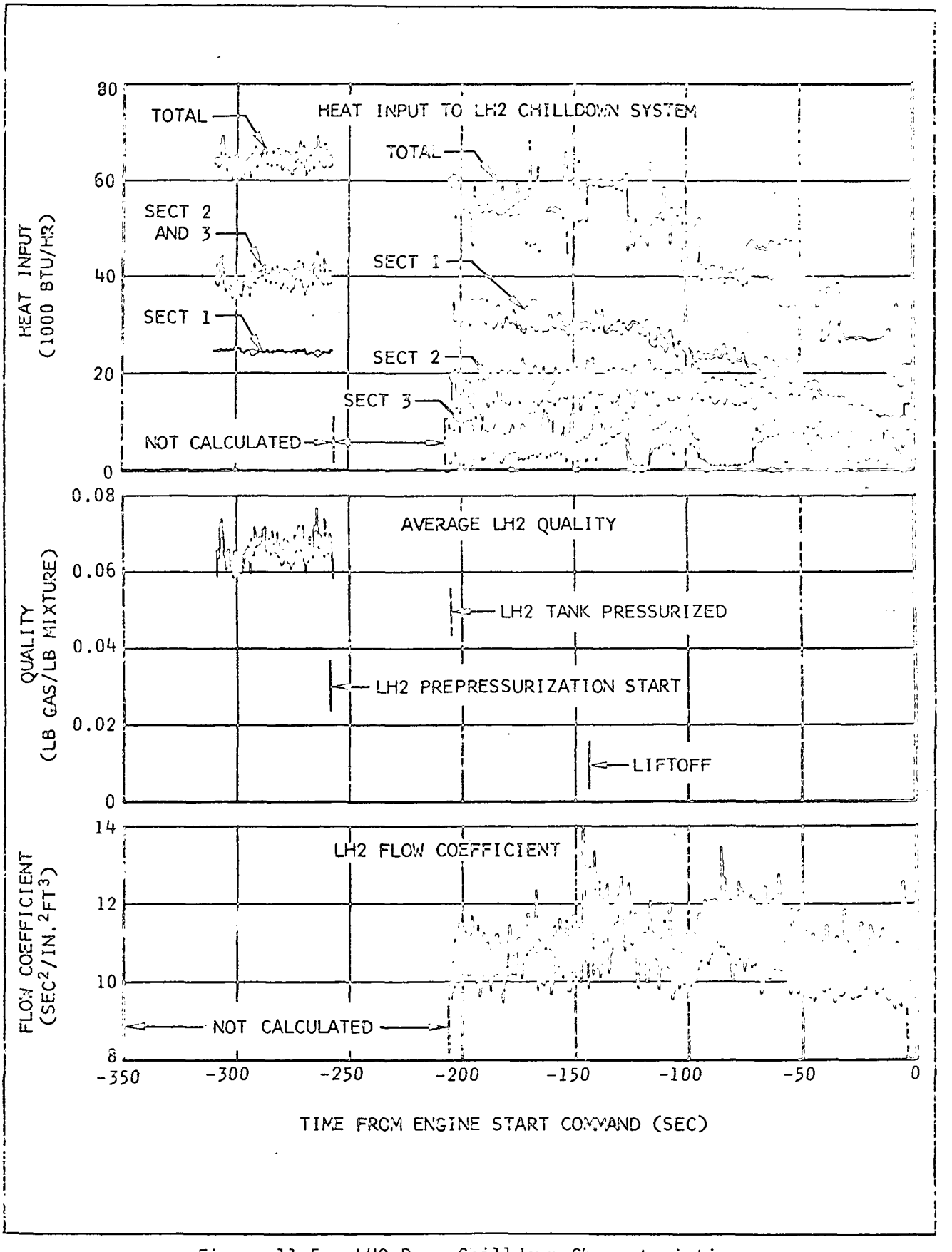

Figure 11-5. LH2 Pump Chilldown Characteristics

24 October 1966

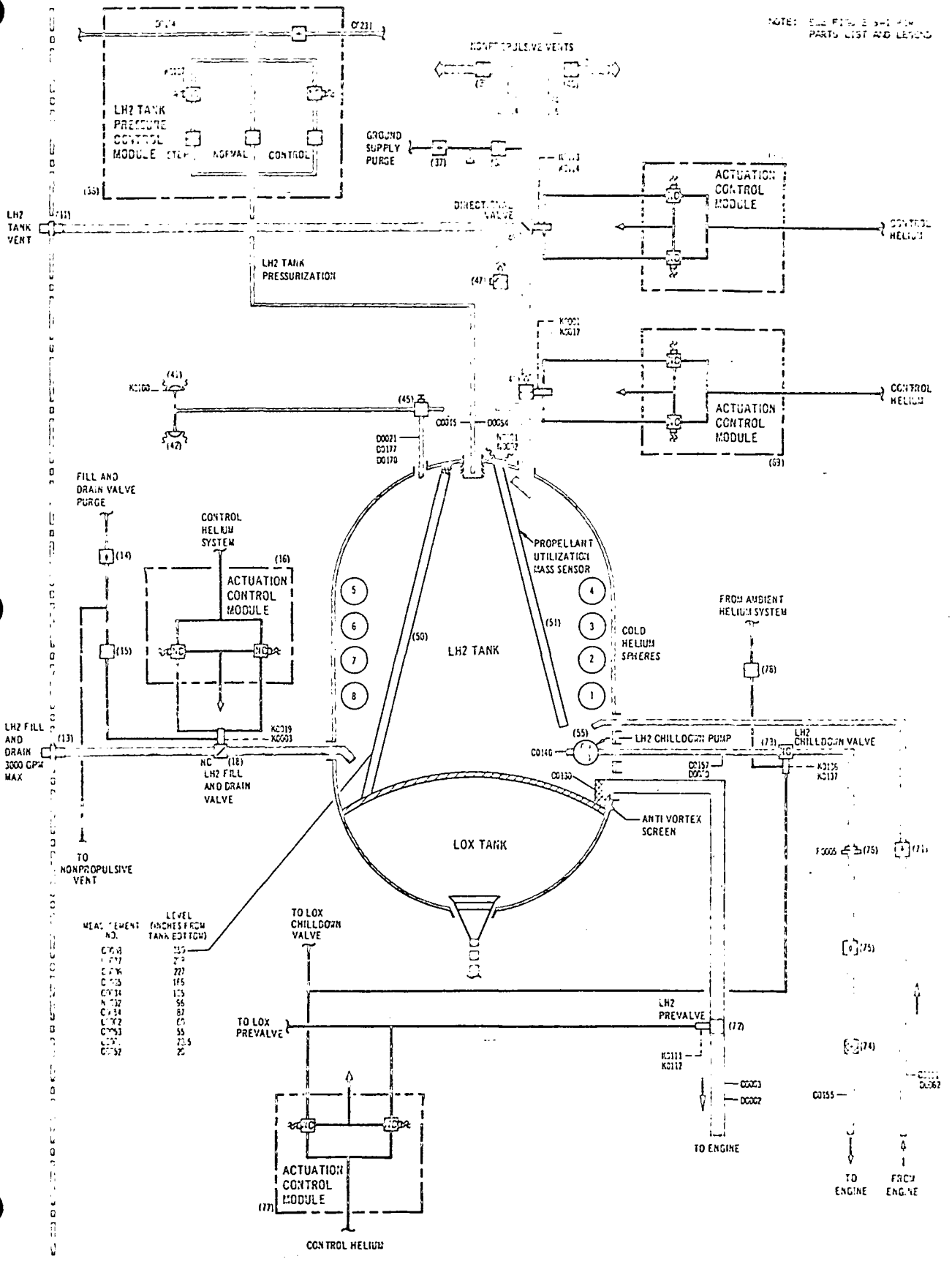

Figure 11-6. LH2 Supply System

24 October 1966

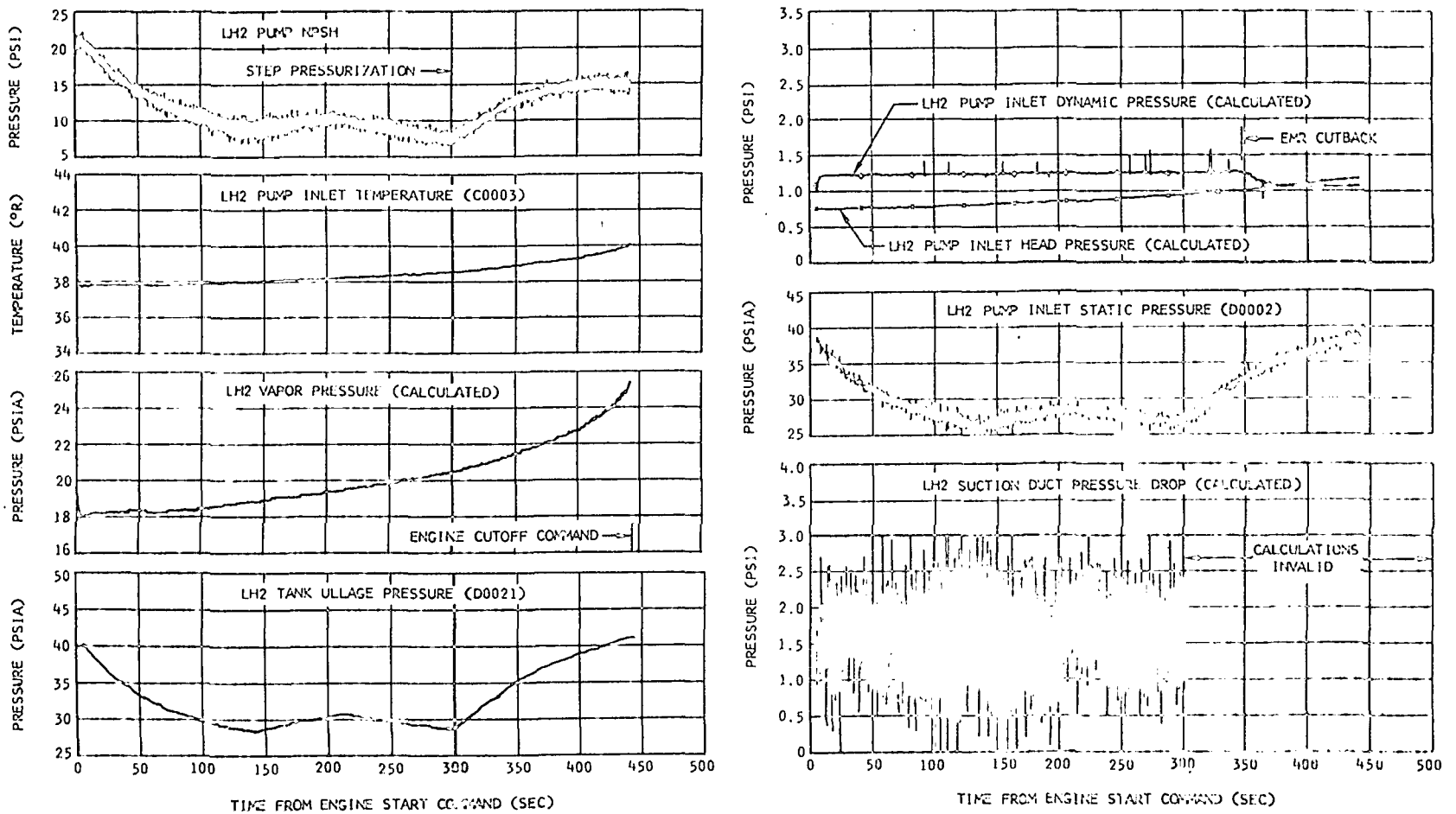

Figure 11-7. LH2 Pump Inlet Conditions

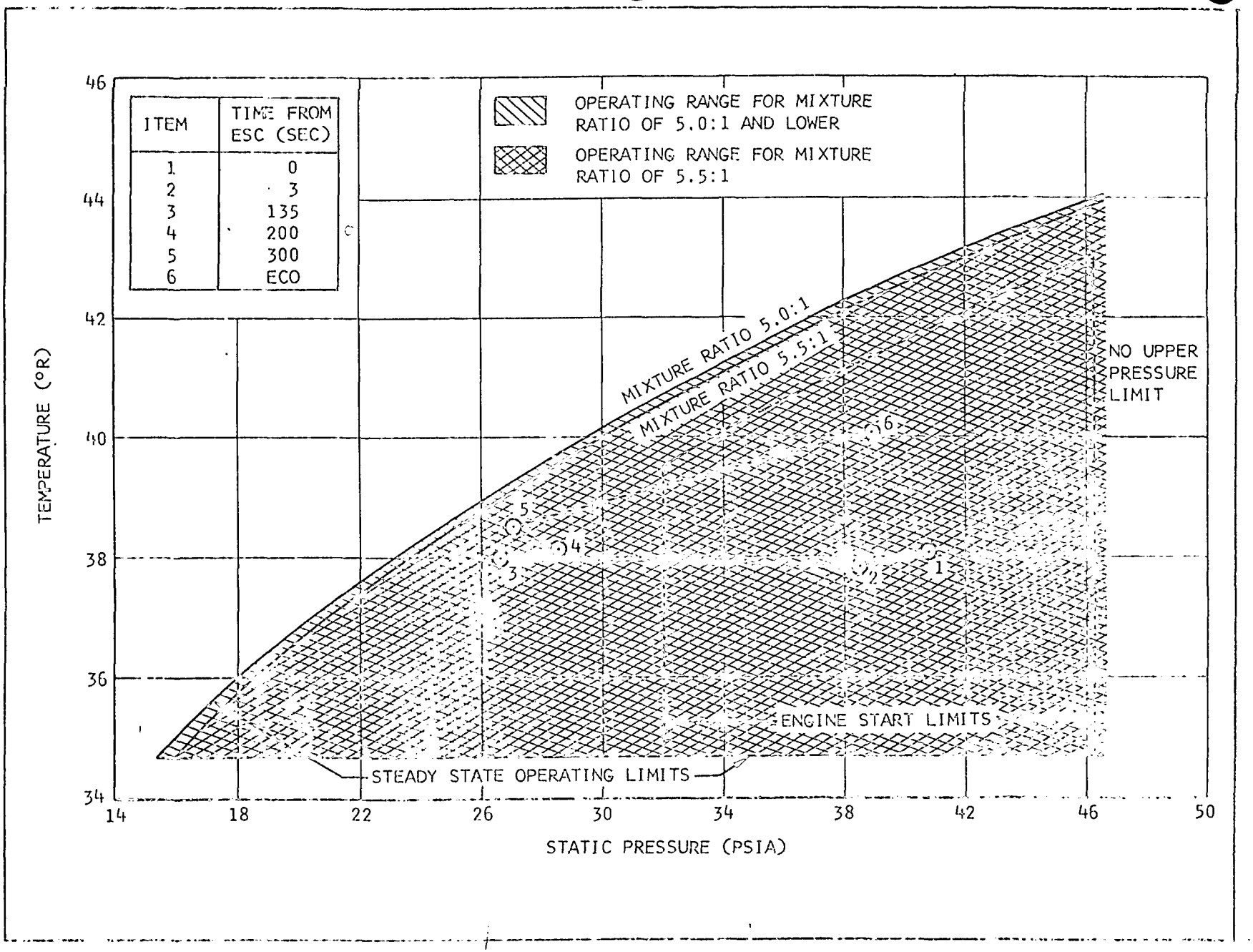

Figure 11-3. LH2 Pump Inlet Conditions During Firing

12. AUXILIARY PROPULSION SYSTEM

The auxiliary propulsion system (APS) flight data indicate that the two APS modules operated very well. The individual engine performance was as expected, agreeing well with the engine manufacturer's test data obtained at simulated altitude conditions. The pulsing sequences of the six engines show that the modules were functioning as required to perform the attitude corrections desired. The auxiliary propulsion system configuration is shown in figure 12-1.

Approximately 1.0 sec after cutoff of the S-IB outboard engines, the APS was activated to provide roll control during S-IVB powered flight. Following J-2 cutoff, APS pitch and yaw control was activated to maintain the vehicle (S-IVB and payload) in the desired attitude. After this time, the two APS modules functioned to compensate for disturbances to the S-IVB vehicle.

12.1 APS Module No. 1

All systems in module No. 1 operated satisfactorily. No difficulties were encountered during flight. The overall engine mixture ratio (EMR) of module No. 1 was 1.62 which agrees well with the nominal value of 1.65.

12.1.1 Module No. 1 Oxidizer System

The operation of the oxidizer system was as expected. The bellows extension and oxidizer quantity available during flight are shown in figures 12-2 and 12-3. The oxidizer temperature is shown in figure 12-4. The module No. 1 oxidizer bellows extension prior to the activation of the APS was 9.93 in. with the oxidizer temperature at 547 deg R. This is equal to an oxidizer mass of 39.6 lbm. The flight data received from the APS system at RO +940 sec (prior to loss of signal) indicated that the module No. 1 oxidizer bellows extension was 6.86 in. with the oxidizer temperature at 549 deg R. Therefore, 27.3 lbm of oxidizer remained, and 12.3 lbm or 31.1 percent of the oxidizer was used during the mission from module No. 1.

12.1.2 Module No. 1 Fuel System

The operation of the fuel system was normal with no apparent difficulties

encountered. The fuel bellows extension and fuel quantity available versus mission time are presented in figures 12-2 and 12-3. The fuel temperature is shown in figure 12-4.

The fuel bellows extension of module No. 1 prior to the initiation of the APS operation was 10.06 in. with the fuel temperature at 547 deg R. This is equivalent to 24.4 lbm of fuel. At RO +940 sec, the bellows extension was 6.91 in. with the fuel temperature at 547 deg R. Therefore, 16.8 lbm of fuel remained and 7.6 lbm or 31.1 percent of the fuel was used during flight.

12.1.3 Module No. 1 Helium Pressurization System

The module No. 1 helium pressurization system operated normally with no problems encountered. Prior to APS firing, the helium sphere pressure was 3,037 psia at a helium temperature of 546 deg R giving an initial helium mass of 0.300 lbm. At RO +940 sec, the mass of helium remaining was 0.265 lbm at a pressure 2,600 psia and a temperature of 535 deg R. Therefore, 0.035 lbm of helium was used by module No. 1 during the flight.

The quantity of helium used determined by the change in propellant ullage volume was 0.038 lbm. The agreement of these two methods of calculating helium usage substantiates the accuracy of the bellows extensions as well as the helium sphere conditions. The regulator outlet pressure was nominal during flight varying from 197 to 203 psia. The desired range is 200 $\pm$5 psia.

12.2 APS Module No. 2

All systems in module No. 2 also operated very well. No difficulties were encountered during flight. The overall EMR of this module during flight was 1.64, which agrees well with the nominal value of 1.65.

12.2.1 Module No. 2 Oxidizer System

The operation of the oxidizer system of module No. 2 was normal throughout flight. The bellows extension and oxidizer quantity during flight are shown in figures 12-2 and 12-3. The oxidizer temperature is shown in

figure 12-4. The oxidizer bellows extension prior to the activation of the APS was 9.91 in. with the oxidizer temperature at 545 deg R. This is equivalent to a mass of 39.6 lbm N_2O_4 in the bellows. At RO +940 sec, the quantity of N_2O_4 remaining in the bellows was 21.9 lbm. The oxidizer temperature at this time was 547 deg R with the bellows extension at 5.51 in. Therefore, 17.7 lbm or 44.7 percent of the oxidizer was used from module No. 2.

12.2.2 Module No. 2 Fuel System

The module No. 2 fuel system operation was normal with no difficulties encountered. The bellows extension and quantity of fuel on board during the flight are shown in figure 12-2 and 12-3.

The fuel bellows extension was 10.00 in. prior to activation of the APS. With the propellant temperature at 544 deg R, the quantity of fuel in the bellows was 24.3 lbm. At RO +940 sec, the fuel bellows extension was 5.56 in. with the temperature at 545 deg R. The mass on board at this time was 13.5 lbm. Therefore, 10.8 lbm or 44.4 percent of the fuel was used from module No. 2.

12.2.3 Module No. 2 Helium Pressurization System

The operation of the helium pressurization system was as expected with no problems encountered. The quantity of helium in the high pressure system at liftoff was 0.299 lbm at a sphere pressure of 3,034 psia and a helium temperature of 547 deg R. At RO +940 sec, the quantity of helium remaining in the helium sphere was 0.248 lbm. The sphere temperature and pressure were 540 deg R and 2,435 psia, respectively. Therefore, 0.051 lbm of helium was used. The quantity of helium used determined from the change in propellant ullage volume was 0.053 lbm. As in the case of module No. 1, the helium usages determined by the two methods agree very well and substantiate the accuracy of the bellows extensions and the helium sphere conditions recorded.

The regulator outlet pressure for this module varied from 195 to 203 psia which was within the 200 $\pm$5 psia required band.

12.3 Engine Performance

Since the minimum pulse width of the APS engines is 0.065 sec, data used in the evaluation of engine performance must be recorded continuously. The only APS engine data from the S-IVB-202 flight meeting this requirement were the engine chamber pressures. By integrating the chamber pressure and multiplying by the thrust coefficient (C_f) and the throat area (A_t), the total impulse for each pulse of an engine was determined. Figure 12-5 shows the accumulative total impulse of each module as a function of mission time. Total accumulated impulse during the flight was 5,194 lb-sec for module No. 1 and 7,651 lb-sec for module No. 2. A discussion of the APS control performance during powered flight and the coast phase may be found in sections 19 and 25, respectively.

Table 12-1 shows the APS propellant consumption during the significant events of the flight.

Roll control during S-IVB powered flight required 4.5 percent of the available APS propellants. The greatest usage was from module No. 2, which consumed 5.2 percent of its propellants.

The largest propellant consumption (21 percent of the available APS propellants) occurred during service propulsion system (SPS) impingement. The steady-state firings of engines 1-1, 2-2, and 2-3 accounted for most of the consumption and provided a means of calculating the steady-state propellant flowrates through the engines. The propellant flowrates through engine 1-1 were 0.308 lbm/sec and 0.190 lbm/sec for oxidizer and fuel, respectively. The engine manufacturer's test data indicate nominal flowrates for this engine of 0.310 lbm/sec for oxidizer and 0.190 lbm/sec for fuel.

Since engines 2-2 and 2-3 were firing together, a combined flowrate was calculated. The combined oxidizer flowrate was 0.657 lbm/sec and the combined fuel flowrate was 0.379 lbm/sec. The corresponding flowrates determined during the engine manufacturer's testing were 0.617 lbm/sec oxidizer and 0.376 lbm/sec for fuel. From the above comparisons, it is evident that the propellant flowrates during S-IVB-202 flight were consistent with those obtained during the engine manufacturer's hot firing tests.

The average specific impulse for the flight was 260 sec for module No. 1 and 269 sec for module No. 2. These values are higher than previous flights due to the relatively long steady-state pulses on engines 1-1, 2-2, and 2-3 during SPS impingement.

In general, APS performance and operation were very good. Although APS usage was above nominal, propellant residuals indicate the system was more than adequate for control requirements during flight.

TABLE 12-1
APS PROPELLANT CONSUMPTION

EVENTS	MODULE NO. 1				MODULE NO. 2			
	OXIDIZER		FUEL		OXIDIZER		FUEL	
	MASS (lbm)	PERCENT USED	MASS (lbm)	PERCENT USED	MASS (lbm)	PERCENT USED	MASS (lbm)	PERCENT USED
Powered roll control	1.5	3.8	1.0	4.1	2.0	5.0	1.3	5.3
Initial convergence first LOX vent disturbance	1.5	3.8	1.0	4.1	1.2	3.0	0.8	3.3
S-IVB/spacecraft separation disturbance	1.1	2.8	0.6	2.4	0.7	1.8	0.4	1.6
SPS impingement	5.3	13.4	3.2	13.1	11.4	28.8	6.9	28.4
Second LOX limit cycle until bulkhead failure	2.9	7.3	1.8	7.4	2.4	6.1	1.4	5.8
Totals	12.3	31.1	7.6	31.1	17.7	44.7	10.8	44.4

EMR Average Module 1:1.62
EMR Average Module 2:1.64

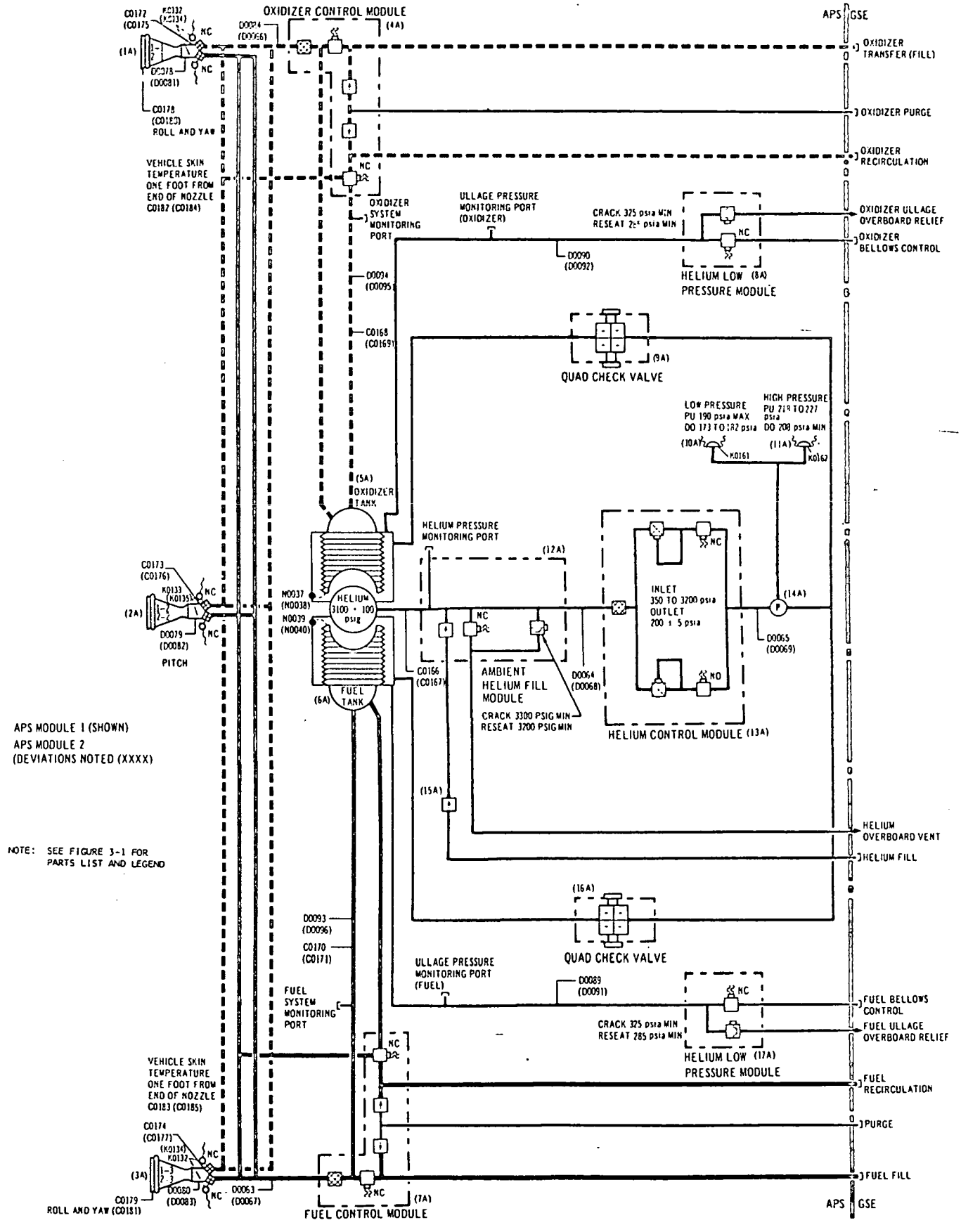

Figure 12-1. Auxiliary Propulsion System and Instrumentation

24 October 1966

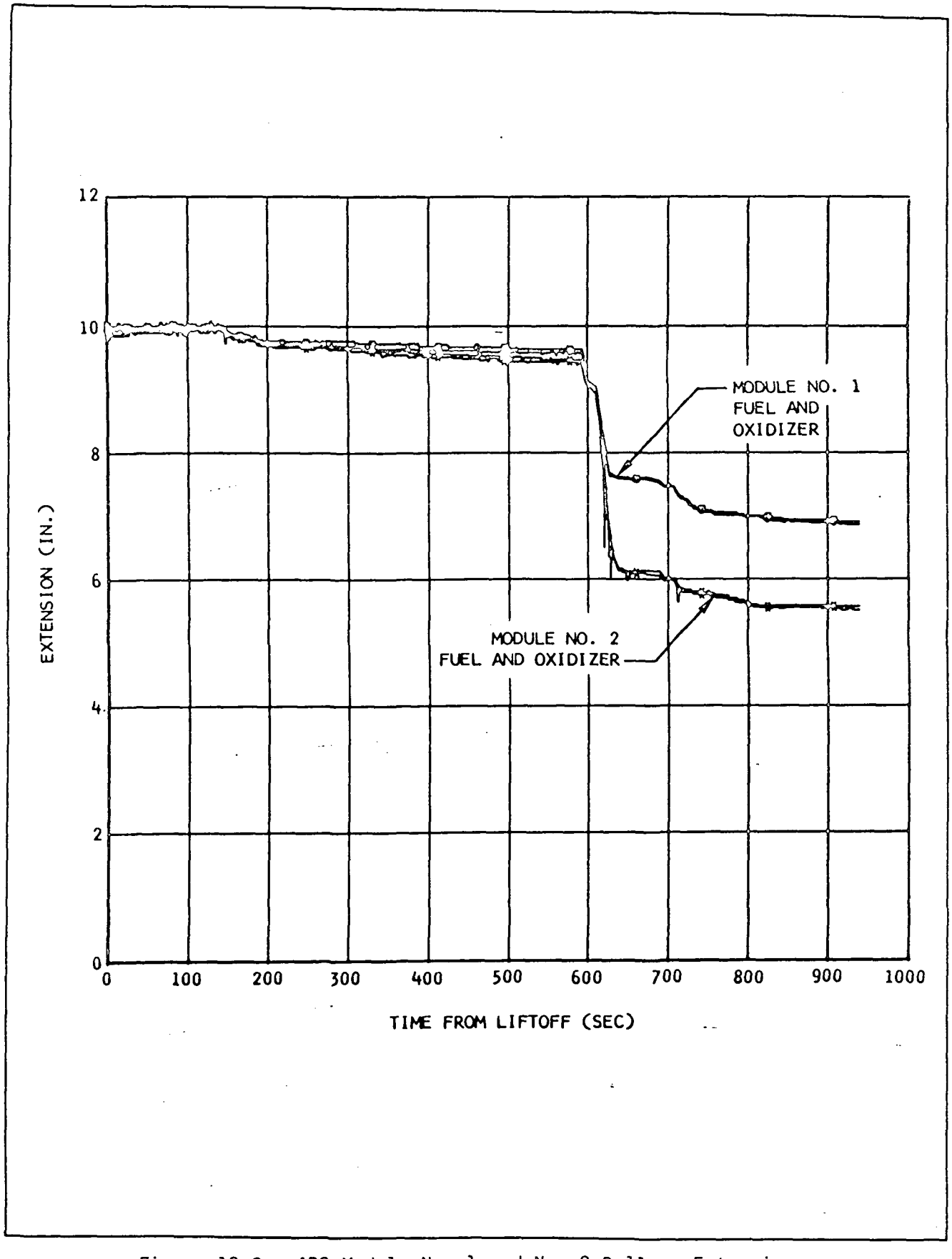

Figure 12-2. APS Module No. 1 and No. 2 Bellows Extension

24 October 1966

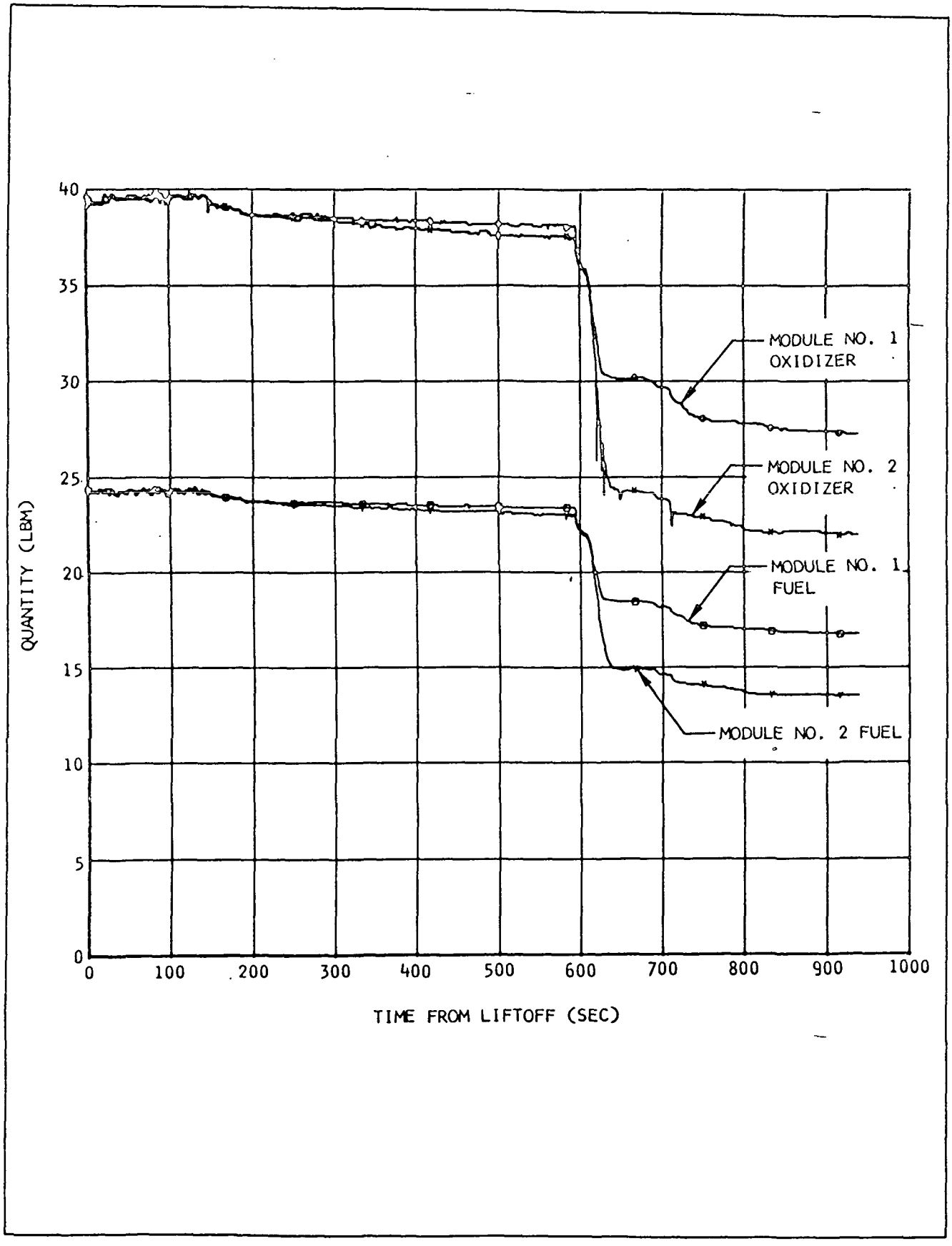

Figure 12-3. APS Module No. 1 and No. 2 Propellant Quantity

24 October 1966

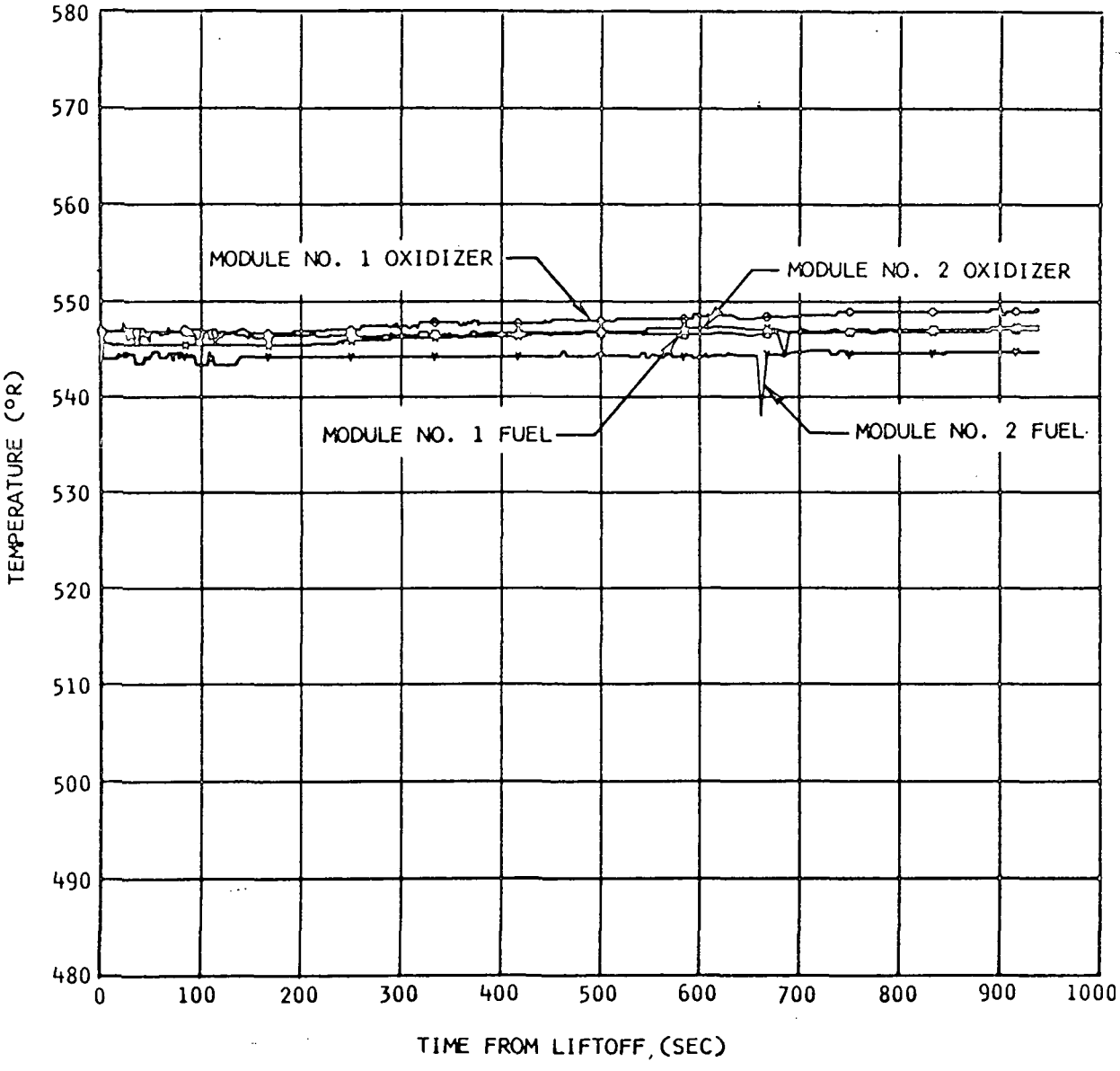

Figure 12-4. APS Module No. 1 and No. 2 Temperatures

24 October 1966

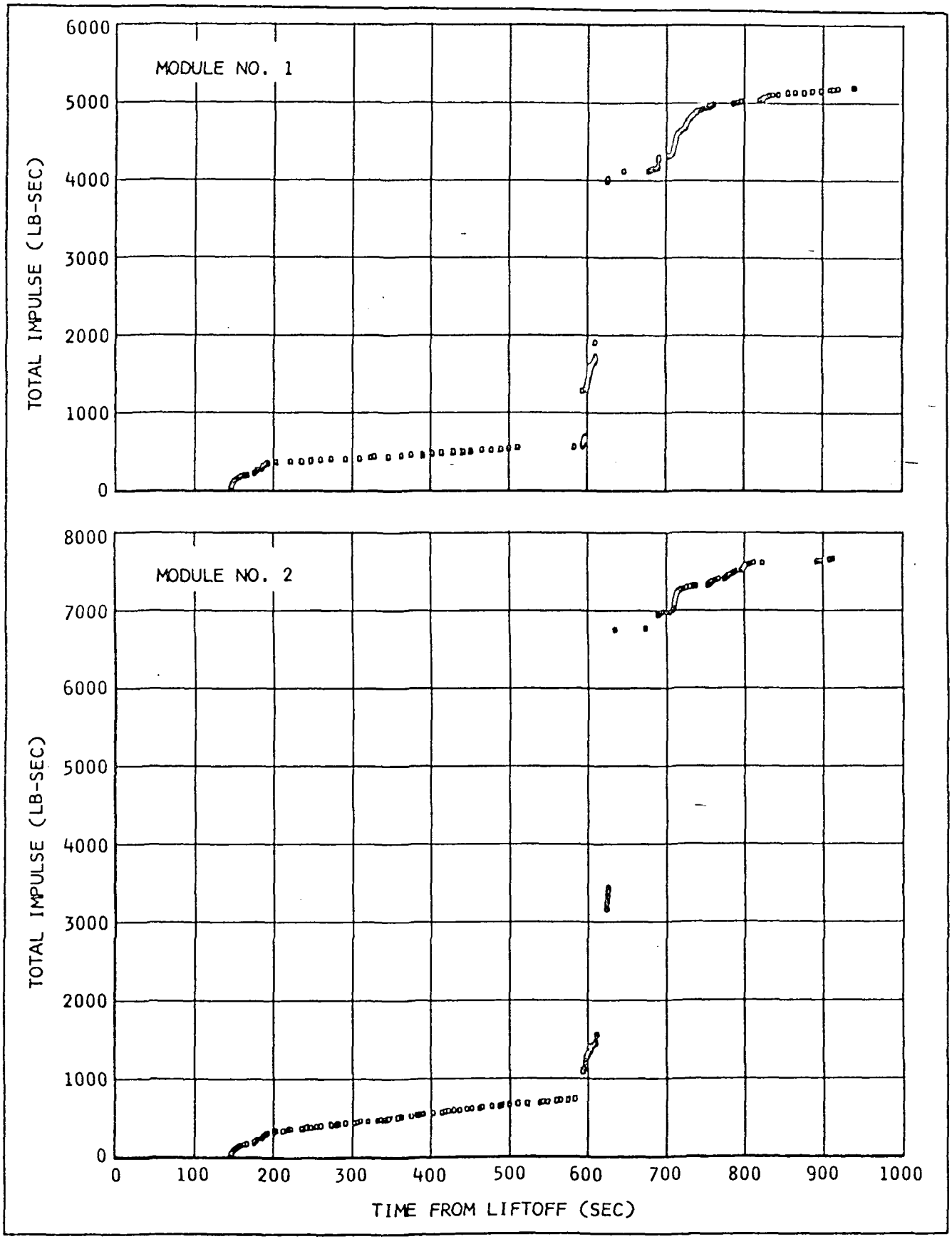

Figure 12-5. APS Module Total Impulse

24 October 1966

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13. PNEUMATIC CONTROL AND PURGE SYSTEM

The pneumatic control and purge system (figure 13-1) performed satisfactorily throughout the flight. The helium supply to the system was adequate for both pneumatic valve control and purging, the regulated pressure was maintained within acceptable limits, and all components functioned normally. The only problem observed was a temporary high helium leakage rate from the LOX chilldown pump motor container during LOX loading.

13.1 Ambient Helium Supply

The ground support equipment helium supply was isolated at liftoff. Ambient helium sphere pressure and temperature histories are presented in figure 13-2. Conditions at significant times were as follows:

Time	Pressure (psia)	Temperature (°R)
Liftoff	2,905	460
Engine Start Command	2,644	448
Engine Cutoff Command	2,605	451

Calculations indicate that the pneumatic sphere was loaded with 1.11 lbm of helium at liftoff and that 1.024 lbm remained at engine cutoff (figure 13-2). The following is a breakdown of helium consumption during various phases of flight:

Period	Usage Rate (scfm)
Boost	2.75
S-IVB engine operation	0.20
Engine cutoff and LOX vent	30.5

This usage includes a constant bleed of 185 scim.

13.2 Pneumatic Control

The pneumatic control system performed satisfactorily. The pneumatic control helium regulator operated at a pressure of 494 to 538 psia. During periods of high pneumatic system usage, the control pressure dropped as low as 397 psia. These momentary drops have occurred on all previous tests and are considered normal. Pneumatic control system pressure decreased after engine cutoff. This decrease was more gradual than during the S-IVB-201 flight.

13.3 Ambient Helium Purges

Eleven purge functions were satisfactorily accomplished throughout the countdown, although trouble was experienced with the LOX chilldown pump motor container during LOX loading. The purge function characteristics, gas sources, and purge periods are listed in table 13-1. A purge of the LOX ullage pressure sensing line was added after the countdown demonstration test (CDDT) to prevent LOX from entering the line and causing a pressure oscillation as it did during the CDDT.

At the initiation of LOX loading, the LOX chilldown pump motor case pressure decreased to ambient. This was first attributed to a failure of the chilldown pump purge module. However, investigation of available data revealed that during the first phases of LOX loading, the chilldown pump helium seal leakage increased to a rate so high that the supply of purge gas through the chilldown pump purge module was unable to maintain a noticeable pressure in the motor container. After 1 hr 15 min, the seal leakage, for no apparent reason, decreased to a level that allowed proper pressure in the motor container and, therefore, continuation of the launch preparations. There were no discrepancies in this system during the terminal count or flight.

All system pressures were normal during preparations for LOX loading of the S-IVB. Prior to the initiation of LOX loading, the purge supply was turned on (limited to 950 scim by orifices) and the motor case vent was opened to purge the motor case. After 15 min, the vent valve was closed and the motor case pressure increased to 52 psia, as expected.

It then cycled between 52 and 49 psia as the pressure switch picked up and dropped out. Data show that 4 to 7 min were required for the pressure to decay from 52 to 49 psia, which indicates an unusually low seal leakage. However, since a series of data dropouts occurred during this time period, it is assumed that seal leakage was probably nominal and that the switch cycled every 1 to 2 min.

At 1322:18 GMT the rate of motor case pressure decrease gradually became more rapid as indicated by increasingly shorter cycle times from pickup to dropout of the motor case pressure switch. These times are progressively 50, 37, 26, 9.5, 2.5, 1.1, and 0.4 sec. After the last cycle the motor case pressure continued to decay to ambient.

Such a loss in pressure might possibly be explained by the following:

a. Failure of the purge supply valve (item* 51, figure 13.1)

b. Failure of the controlling pressure switch (item* 59) to drop out

c. Failure of the motor case vent valve (item* 61) to stay closed or to seal

d. Failure of the motor case relief valve (item* 60)

e. An increase in the leakage rate of the helium seal (item* 57)

Examination of the various failure mode possibilities produced the following results:

a. Failure of the supply valve was the first mode to be investigated. To check for this or a plugged supply orifice, the supply of helium was shut off and the supply pressure carefully observed. The recorded data show a flowrate of approximately 1,000 scim out of the system. This indicates that the orifice was not plugged, the purge valve was open, and the pressure switch had dropped out.

b. Failure of the pressure switch is discussed in a, above.

---

*Item number indicates location on figure 13.1.

c. It is very unlikely that failure of either the motor case vent valve or the relief valve would be progressive as indicated by the data. The pressure never reached a value that could be expected to "crack" the relief valve; and, therefore, there is no understandable way for it to begin leaking and later repair itself and cease leaking.

d. A review of the pump test history revealed that, during the production acceptance test, sporadic high leakages of the helium seal were observed. This occurred during pump chilldown as in this instance. Leakage rates of 1,700 scim, almost twice the supply rate and lasting for 5 to 10 sec, were noted three times. The continuation of this situation for more than an hour cannot be explained. However, the helium seal appears to be the most probable cause of the problem.

At 1435:40 GMT the motor case pressure started to increase to the normal level. The increase was at a normal rate and occurred during a period of quiescence with regard to other vehicle activities, in spite of earlier reports that the pressure recovery was the result of a system "pressure shock". This increase cannot be explained.

After this recovery, the pressure decay rate was higher than normal but low enough to allow the supply system to maintain the pressure between the normal limits. The cycling occurred at 5 cpm, 5 to 10 times faster than normal. Later in the countdown, the cycle period returned to normal and then, after the chilldown pump was started, the seal leakage, as expected, reduced.

All data points toward unusual behavior of the chilldown pump helium seal. The leakage rate was normal when the system was first activated; the rate increased as the seal was chilled down; the leakage then reduced to a tolerable but unusually high rate; and finally returned to normal.

The seal configuration flown on S-IVB-202 has been replaced by an improved design with a much lower leakage rate. The new seal has not shown any tendency to become unseated as the S-IVB-202 seal did. All future stages will use the new seal; therefore, no design changes are required.

TABLE 13-1
S-IVB-202 PURGE FUNCTIONS

Item No.	Purge Function	Purge Helium Source			Orifice Type/Size	Nominal Flowrate
		Ground Phase	Boost	S-IVB Flight Phase		
1	LOX tank vent valve	Facility*			0.024 in.	65 scfm at 3000 psig
2	Engine fuel turbine seal cavity	Stage+	Stage	Stage	++	Total 6.0 scfm++ at 105-130 psia
3	Engine LH2 pump seal cavity	Stage	Stage	Stage		
4	Engine LOX pump seal	Stage	Stage	Stage		
5	GG GH2 injector	Stage	Stage	Stage		
6	LOX chilldown pump container	Stage	Stage	Stage	Sintered	950 ±95 scim at 475 psid
7	LOX fill and drain valve housing	Facility			Sintered	15 scim at 3200 psid
8	LH2 fill and drain	Facility			Sintered	15 scim at 3200 psid
9	LH2 nonpropulsive vent	Facility			Sintered	1728 scim 3200 psig
10	LOX ullage sense line	Facility			Sintered	3.26 scfm at 3000 psid
11	LH2 chilldown shutoff valve	Facility			Sintered	14 scfm at 3000 psid

* Facility = GSE console A (DSV-4B-319)

\+ Stage = S-IVB regulated pneumatic control supply

++ Common 0.023 in. dia orifice in engine pump purge control module

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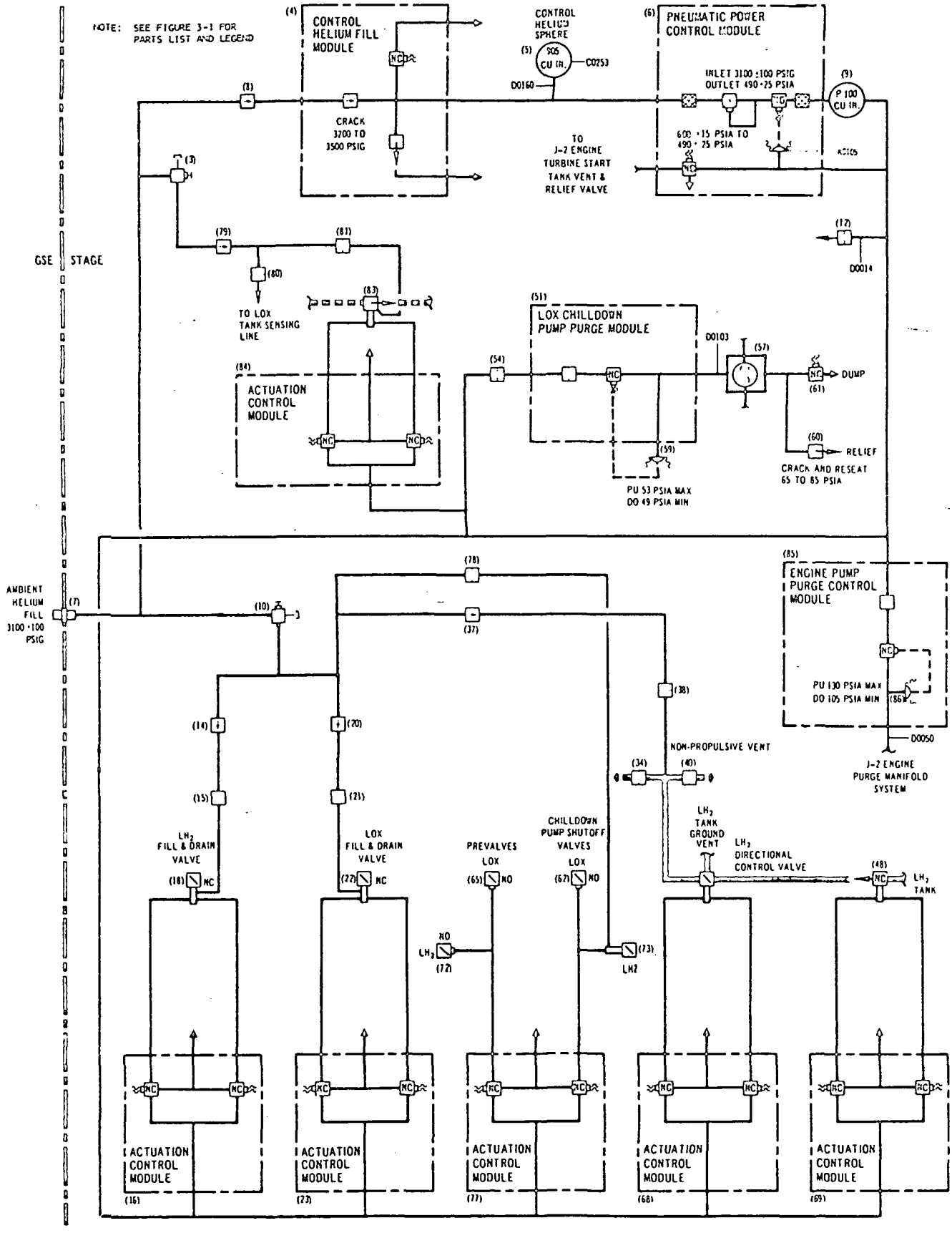

Figure 13-1. Pneumatic Control and Purge System

24 October 1966

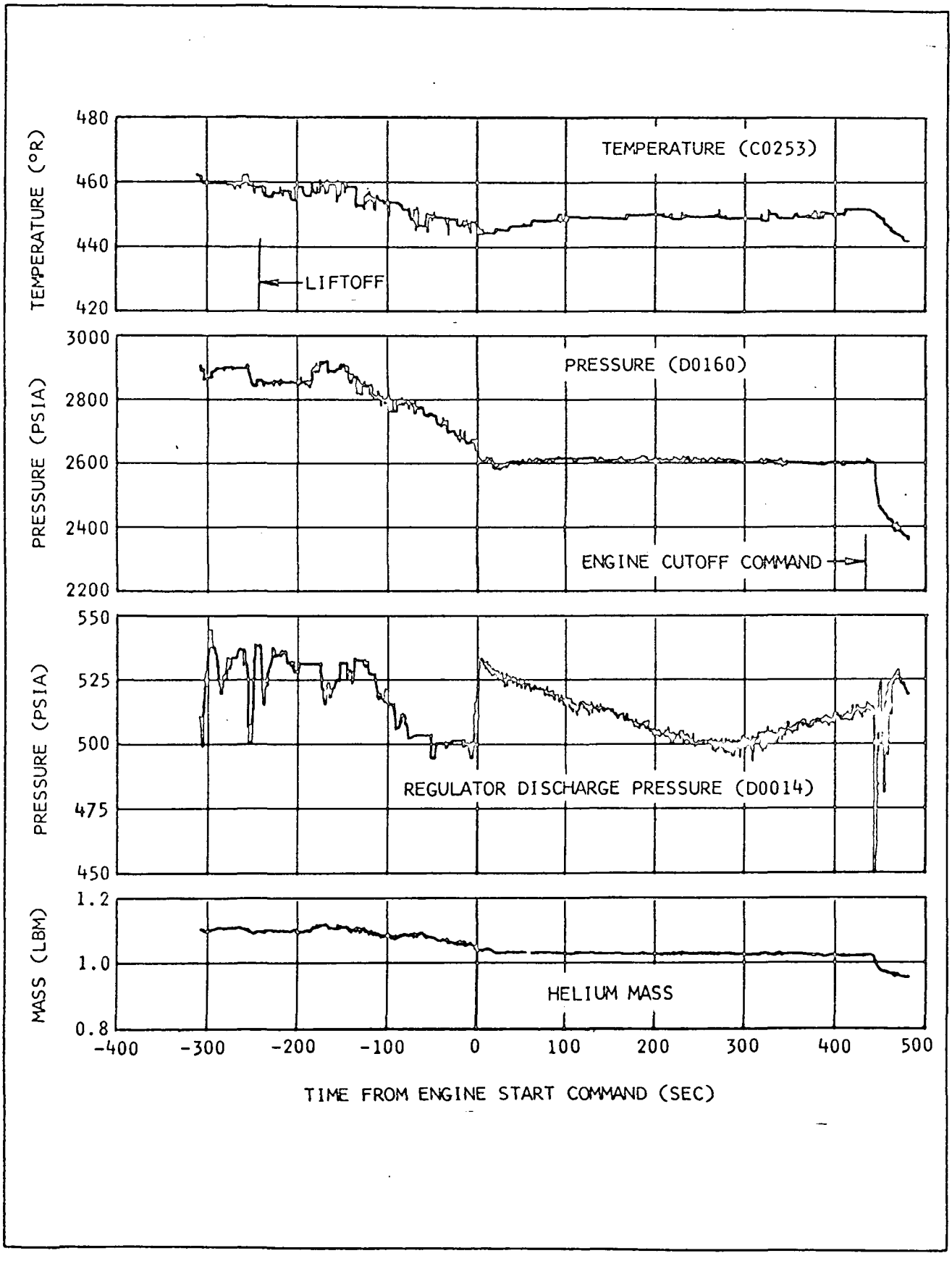

Figure 13-2. Pneumatic Control and Purge System Performance

24 October 1966

14. PROPELLANT UTILIZATION

The propellant utilization (PU) system accomplished all of its design objectives for loading and PU control. The propellant load, as indicated by the PU system, was within -0.07 percent LOX and +0.27 percent LH2 of the actual loads as determined by the best estimate method. Predicted loading accuracy was ±1.12 percent. The PU system operated satisfactorily in the closed-loop mode with PU valve cutback occurring at ESC +330.1 sec. This cutback time was 24.1 sec later than predicted but was well within the ±45 sec tolerance.

The engine mixture ratio (EMR) following the PU cutback transient was 4.80:1 as compared to a predicted value of 4.784:1. Based on extrapolation from the conditions at cutoff, depletion would have occurred with 324 lbm of usable propellant on board compared to a guaranteed maximum usable propellant residual of 575 lbm.

14.1 Propellant Mass History

Propellant mass history during the flight is presented in table 14.1. Acceptance test data and the flow integral method of mass determination were used to calibrate the PU system capacitance mass sensors to achieve the desired loading accuracy for flight.

Engine analysis mass values shown in table 14-2 are based on analysis of propellant flowrates using engine influence equations, engine flowmeter data, and thrust chamber data. Residual mass values at engine cutoff are based upon a weighted average of PU system, point level sensor data, and flight reconstruction.

The flow integral method consists of determining the mass flowrate of LOX and LH2 and integrating as a function of time to obtain total consumed mass during firing. The initial full-loaded mass on board was determined by adding the following items to the total consumed mass:

	LOX (lbm)	LH2 (lbm)
Propellant Residual (at ECC)	4,015	1,600
Net Mass Lost Through Boil-off (from RO to ECC)	180	- -

Statistical methods were used to combine the propellant mass history results of the three programs into a single set of values. These values define the flow integral actual mass history.

14.1.1 Propellant Loading

Table 14-3 is a summation of loaded mass and percentage deviations from desired, flow integral, and statistical weighted average at S-IVB Engine Start Command (ESC). This time is sufficient for propellant load determination since no propellants are consumed from liftoff to Engine Start Command.

The following is a tabulation of the desired, indicated, actual, and flow integral propellant loading at liftoff for the S-IVB-202 flight:

	LOX (lbm)	LH2 (lbm)	TOTAL (lbm)
Desired Full Load (Predicted)	193,273	37,121	230,394
Indicated Full Load (PU Reading)	193,333	37,165	230,498
Actual Full Load (Best Estimate)	193,473	37,064	230,537
Flow Integral Full Load	193,376	36,619	229,995

The PU system and propellant tank design are such that each propellant must be loaded in the unpressurized state to an indicated mass that is larger than the desired mass. The apparent overload is required to correct for effects of pressurization on tank structural deflection and the attendant variation of capacitance readout of the PU mass sensors. PU readout is also affected by changes in ullage gas density during pressurization. Use of a preselected unpressurized overload value during loading, as indicated by the PU coarse mass ratio, will result in an accurate mass indication when the tank is pressurized. S-IVB-202 PU system coarse mass readings for unpressurized propellant loading were calculated from acceptance test data and preflight data.

The coarse mass ratio values (coarse mass reading/excitation voltage) for the flight were as follows:

PROPELLANT	UNPRESSURIZED	PRESSURIZED
LOX	0.9778	0.9737
LH2	0.9095	0.9040

14.1.2 Residuals

Propellant residuals were determined at Engine Cutoff Command (ECC) from the PU system and the level sensors. LOX level sensor L0006 activated during flight; however, LOX level sensor L0005 was inoperative prior to and during flight. Two LH2 level sensors (N0032 and L0002) activated during flight. Table 14-4 presents a residual comparison between level sensors and the PU system at level sensor activation time and at Engine Cutoff Command.

14.2 PU System Analysis

14.2.1 PU System Calibration

The PU system was calibrated in accordance with the mass to capacitance relationship established by the engine flow integral analysis using acceptance firing engine data. The deviation of the PU indicated mass from the statistically weighted best estimate mass at liftoff was -0.07 percent for LOX and +0.27 percent for LH2.

14.2.2 Non-Linearities

Figures 14-1 and 14-2 present flight non-linearities determined from the sum of the predicted basic acceptance firing mass sensor non-linearity, cg offset, and inflight dynamic tank geometry change non-linearities.

The predicted basic acceptance firing mass sensor non-linearity was generated from the normalized vendor mass sensor and nominal ground loading tank volume data. The cg offset non-linearity was caused by the propellant level not being perpendicular to the vehicle centerline. This non-linearity was determined from the capacitance mass sensor location and the vehicle cg offset data. The flight dynamic

non-linearity factor was caused by the changing propellant tank geometry due to vehicle acceleration, propellant tank skin temperature, and pressure differential across the tank structure.

Figures 14-3 and 14-4 are correction factors for the PU indicated mass. These factors are not normalized to the Engine Start Command or cutoff masses. The corrected PU mass is obtained by subtracting the correction from the indicated PU sensor mass.

14.2.3 System Response

The nominal predicted S-IVB-202 flight PU valve history is given in figure 14-5. The predicted PU valve history is based on the following:

a. 202 acceptance firing mismatch non-linearities (derived)

b. 202 sensor errors due to cg offset (predicted)

c. 201 sensor errors due to tank geometry changes (predicted)

d. 202 manufacturing sensor non-linearities (LOX sensor E-5 and LH2 sensor E-7)

e. 202 pump inlet conditions, pressurization and boiloff rates, and auxiliary drive (predicted)

f. 202 engine (J-2016) tag values, influence coefficients and ΔEMR vs valve position characteristics

g. 202 desired loads

h. 202 desired calibration (bridge gain ratio = 4.8).

The above conditions result in a nominal valve cutback of ESC +306 sec. Propellant utilization system cutback occurred at ESC +330.1 sec. The actual mean level of valve position after cutback was approximately 0.2 deg lower than predicted.

The difference between the predicted and the actual valve traces were caused by the following:

		CUTBACK TIME DEVIATIONS (sec)	VALVE POSITION SHIFT (deg)
1.	Electronics assembly calibration error	+22.5	+0.65
2.	Differences between S-IVB-201 and S-IVB-202 sensor errors due to tank geometry	-8.8	-0.40
3.	Open loop flowrate deviations	-3.2	-2.45
4.	Indicated loading deviations	+6.3	0.0
5.	Mass/capacitance calibration deviations	15.2	1.64
6.	Difference between predicted and actual total flight non-linearities	-7.1	+0.36
7.	Slosh effect	-0.8	0.0
	Total	24.1	-0.2

The following paragraphs include the analysis of these deviations.

14.2.3.1 Electronics Assembly Calibration Error

An attempt was made to adjust the mass/capacitance relationship derived from the acceptance firing so as to compensate for the effects of cg offset and tank geometry changes. These corrections were applied incorrectly and resulted in a calibration error in the electronics assembly. This error is equivalent to a +0.241 percent LOX calibration error and a -0.723 percent LH2 calibration error. The effect of this error is to increase PU valve cutback time 22.5 sec and to shift the PU valve +0.65 deg after cutback. This calibration error is not to be confused with errors in the mass/capacitance relationship derived from the acceptance firing flow integral. It did not cause a propellant load error and affected only the slope of the sensor calibration and the PU system residual. The residual was increased by 50 lbm and the calibration slope error affected the valve profile as stated above.

14.2.3.2 Difference Between S-IVB-201 and 202 Sensor Errors Due to Tank Geometry Changes

The predicted sensor errors due to tank geometry changes for 202 flight were not available at the time of the original prediction (predicted sensor errors for S-IVB-201 flight were used). The correct predicted flight dynamics effect for S-IVB-202 flight decreases PU valve cutback time by 8.8 sec and shifts the PU valve after cutback -0.4 deg.

14.2.3.3 Revised Engine Tag Values

New engine tag values were presented to DAC at the Flight Evaluation Working Group meeting of 31 August 1966 by MSFC. The new engine tag values resulted in a slight shift in engine performance but had a negligible effect on PU valve cutback time or the mean value of valve position after cutback.

14.2.3.4 Open Loop Flowrate Deviations

The effect of the differences between the predicted and actual pump inlet conditions, pressurization and boiloff rates, and auxiliary drive for S-IVB-202 flight was to decrease cutback time 3.2 sec and shift the valve after cutback -2.45 deg.

14.2.3.5 Indicated Loading Deviations

Indicated loading deviations are the difference between the actual and the desired indicated loads at liftoff. The indicated loading errors were +10 lbm LOX and -86 lbm LH2. The effect of these errors was to cause cutback time to occur 6.3 sec later than predicted.

14.2.3.6 Calibration Errors (CA27 Flow Integral Mass/Capacitance)

Calibration deviations at Engine Start Command were +0.56 percent LOX and +0.69 percent LH2 thus causing the initial masses to be underloaded by the above percentages. Calibration deviations at ECC were -0.05 percent LOX and -0.533 percent LH2. The slope deviations between ESC and ECC were +0.620 percent LOX and +1.23 percent LH2. These slope deviations combined with the electronics calibration errors cause the desired

desired bridge gain ratio (BGR) of 4.8:1.0 to actually be 4.78:1.0. The actual EMR at ECC was 4.73:1.0 thereby indicating an EMR shift of -0.05 mixture ratio units due to total sensor non-linearities at ECC. If the flight had gone to depletion cutoff, an additional EMR tailoff of 0.1 mixture ratio units would have been observed; thereby indicating an EMR shift of -0.15 mixture ratio units due to total sensor non-linearities at depletion cutoff of 4.63:1.0.

The LOX equivalent calibration error between the mass/capacitance end points was -0.607 percent. This LOX equivalent calibration error would cause a 15.2 sec increase in cutback time and a +1.64 deg shift in valve position.

14.2.3.7 Difference Between Predicted and Actual Flight Sensor Non-linearities

The smoothed tank-to-sensor mismatch and manufacturing non-linearities (figure 14-6) were obtained by normalizing curves of PU indicated mass versus flow integral mass. The normalization line was also the actual calibration as calculated from the actual and indicated initial loads and residuals. The tank-to-sensor mismatch and manufacturing non-linearities in terms of normalized capacitance error are shown in figure 14-7. These curves include sensor manufacturing non-linearities.

A comparison of the total flight non-linearities and total acceptance non-linearities (figure 14-6) may be made by removing the cg offset and tank geometry change sensor errors from the total flight non-linearities. This comparison indicates that the flight non-linearities are larger than predicted (acceptance) and the result of this difference is a 7.1 sec decrease in cutback time and a +0.36 deg shift in valve position.

14.2.3.8 Slosh Effect

The PU valve cutback time was reduced approximately 0.8 sec due to LH2 slosh.

14.2.3.9 Postfiring Reconstruction

Combining the factors affecting PU system-response, the predicted cutback time would be increased 24.1 sec and the mean level of valve position after cutback would decrease by 0.2 deg. This gives a close comparison between the actual valve response and the reconstruction shown in figure 14-5. The reconstruction agrees with actual data and, therefore, verifies satisfactory PU system operation. The actual and reconstruction summing point error signal are also in good agreement as shown in figure 14-8.

14.2.3.10 PU Valve and Thrust Response

Figure 14-8 is the telemetry summing point error signal. This error signal was used as the input to the PU electronics mathematical model to generate the PU valve response of figure 14-8. The close agreement between the actual and generated response verifies PU valve response to the summing point error signal. The error signal was biased -0.316 volts for the open-loop calculation.

The S-IVB-202 flight thrust history is compared with the predicted nominal and the three-sigma dispersion band in figure 14-9. The predicted nominal and actual thrust profiles are in close agreement from ESC +400 sec to flight termination. The 24.1 sec late PU valve cutback caused the actual thrust history to vary from the predicted between the nominal predicted cutback and ESC +400 sec. This later than nominal cutback was within the expected cutback tolerance and did not present any problem. Predicted and actual thrust values during the flight are compared in table 14-5 with MSFC limits established for S-IVB-204.

Thrust values during the last 70 sec of burn were affected by the late valve cutback and early cutoff. Late cutback caused part of the cutback transient to occur during the last 70 sec as did early cutoff. Early cutoff also eliminated most of the thrust tailoff that would have occurred if the flight had gone to depletion cutoff. The predicted thrust parameters are based on nominal valve cutback and depletion cutoff.

A valve tailoff of 1.1 deg due to total sensor non-linearities occurred from ESC +425 sec to ECC. The thrust tailoff due to this valve motion was approximately 1,200 lbf. Note that figure 14-5 indicates a gross reduction in valve tailoff due to early cutoff time. Had depletion cutoff occurred, the valve tailoff would be increased 3.3 deg and the total thrust tailoff due to total sensor non-linearities would have been 4,800 lbf during the last 24 sec of burn.

LH2 sloshing as seen by the mass sensor was approximately 422 lbm peak-to-peak at a frequency of 0.25 cps during the last 40 sec of burn. Figure 14-10 indicates a 1 deg peak-to-peak PU valve oscillation due to LH2 slosh. These slosh induced valve oscillations created a 1,000 lbf peak-to-peak thrust oscillation.

14.2.3.11 S-IVB-202 Flight and Acceptance Response

There were no changes to the S-IVB-202 PU system between the acceptance firing and the flight except for the recalibration. Figure 14-11 compares the PU valve traces for the acceptance firing and the flight.

14.3 PU Efficiency

The closed-loop PU efficiency was found to be 99.86 percent based on the extrapolation to depletion of all usable propellants. Using engine consumption rates at cutoff, extrapolation resulted in a total usable residual of 342 lbm LH2. The propellant consumption flowrates at engine cutoff were 77.06 lbm LH2/sec and 347.79 lbm LOX/sec, and represent the summation of the total flow through the engine, the boiloff rates and the GH2 pressurant flowrate at that time. It should be noted that of the 324 lbm LH2 residual, 136 lbm was intentionally biased from the indicated LH2. The electronics assembly calibration error increased the LH2 residual by approximately 50 lbm.

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TABLE 14-1
PROPELLANT MASS HISTORY

EVENT	DESIRED MASS (lbm)			PU SYSTEM CORRECTED* MASS (lbm)			FLOW INTEGRAL MASS (lbm)			TRAJECTORY RECONSTRUCTION (lbm)	STATISTICAL WEIGHT AVERAGE MASS (lbm)		
	LOX	LH2	TOTAL	LOX	LH2	TOTAL	LOX	LH2	TOTAL	TOTAL	LOX	LH2	TOTAL
Liftoff RO +0.933	193,273	37,121	230,394	193,333	37,165	230,498	193,376	36,619	229,995		193,473	37,064	230,537
Engine Start Command RO +145.624	193,273	37,121	230,394	193,333	37,165	231,498	193,376	36,619	229,995	230,541	193,473	37,064	230,537
PU System Activate (ESC +6.004) RO +151.628	190,669	36,591	227,260	192,053	36,780	228,833	192,016	36,286	228,302	228,872	192,018	36,719	228,737
PU Valve Cutback Time RO +475.7	53,875	11,955	65,830	47,192	10,377	57,569	47,180	10,243	57,423	56,946	46,683	10,218	56,901
Engine Cutoff Command RO +588.473	2,858	1,109	3,967	3,975	1,600	5,575	4,015	1,600	5,705	5,649	4,015	1,600	5,615
Total Propellant Consumed (ESC to ECC)	190,415	36,012	226,427	189,358	35,565	224,923	189,361	35,019	224,290	224,892	189,458	35,464	224,922

* Corrected for non-linearities

TABLE 14-2
ENGINE ANALYSIS PROPELLANT MASS

EVENT	FLOWMETER PROGRAM		INFLUENCE COEFFICIENT		THRUST CHAMBER ΔT		FLOW INTEGRAL RESULTS	
	LOX	LH2	LOX	LH2	LOX	LH2	LOX	LH2
Liftoff	194,014	36,765	192,224	36,688	193,885	36,405	193,376	36,619
Engine Start Command	194,014	36,765	192,224	36,688	193,885	36,405	193,376	36,619
PU System Activation (ESC +6.004)	192,650	36,449	190,793	36,341	192,602	36,070	192,016	36,286
PU Cutback (ESC +330.1)	47,335	10,334	46,935	10,260	47,270	10,132	47,180	10,243
Engine Cutoff Command (ESC +442.849)	4,015	1,600	4,015	1,600	4,015	1,600	4,015	1,600

TABLE 14-3
PROPELLANT LOADING SUMMARY

PROPELLANT LOAD	LOX	LH2
Desired (lbm)	193,273	37,121
PU System (lbm)	193,333	37,165
Flow Integral (lbm)	193,376	36,619
Statistical Weighted Average (lbm)	193,473	37,064
DEVIATION FROM DESIRED		
PU System (lbm)	+60	+44
(percent)	0.031	0.119
Flow Integral (lbm)	+103	-502
(percent)	0.053	-1.362
Statistical Weight Average (lbm)	+203	-57
(percent)	0.106	0.154
DEVIATION FROM STAT. WEIGHTED AVERAGE		
PU System (lbm)	-140	+101
(percent)	-.074	0.273
Flow Integral (lbm)	-97	-445
(percent)	-0.052	1.202
DEVIATION FROM FLOW INTEGRAL		
PU System (lbm)	-43	+546
(percent)	-0.022	1.477

TABLE 14-4
PROPELLANT RESIDUAL SUMMARY

RESIDUALS AT LEVEL SENSOR ACTIVATION

LEVEL SENSOR	TIME	L/S MASS	PU MASS	RESIDUALS*
N0032 (LH2)	ESC +384.9	5,879	5,911	1,588
L0002 (LH2)	ESC +436.8	2,110	2,078	1,663
L0006 (LOX)	ESC +402.0	18,696	13,670	4,390

RESIDUAL AT ENGINE CUTOFF COMMAND (ESC +442.9)

	LEVEL SENSOR**	ACCURACY	PU SYSTEM	ACCURACY	WEIGHTED AVERAGE***	ACCURACY	BEST ESTIMATE RESIDUALS†
LOX	4,390	±582	3,975	±600	4,189	±418	4,015
LH2	1,593	±61	1,600	±178	1,594	±58	1,600

* Extrapolated from level sensor activation to Engine Cutoff Command

** Best estimate of extrapolated level sensor residuals

*** Statistically weighted average of level sensor and PU system residuals

† Best estimate from PU system, flow integral, trajectory reconstruction, and level sensor residuals.

TABLE 14-5
THRUST VARIATIONS

TIME PERIOD	MEAN SLOPE (lbf/sec)			MAXIMUM RATE (lbf/sec)			MAXIMUM AMPLITUDE (lbf)		
	ALLOWABLE	ACTUAL	PREDICTED	ALLOWABLE	ACTUAL	PREDICTED	ALLOWABLE	ACTUAL	PREDICTED
PU Valve Hardover at 5.5/1.0 EMR	- - -	- - -	- - -	±500	±60	±100	±2,500	710	±750
Valve cutback +50 sec to ECC -70 sec	- - -	- - -	- - -	±500	N/A	70	±7,500	N/A	±500
ECC -70 sec to ECC	±58	-80	-90	±500	-385*	-450	±2,000	+3,300	2,600

* Value shown is without sloshing. Value including slosh effects is 1,400 lbf/sec.

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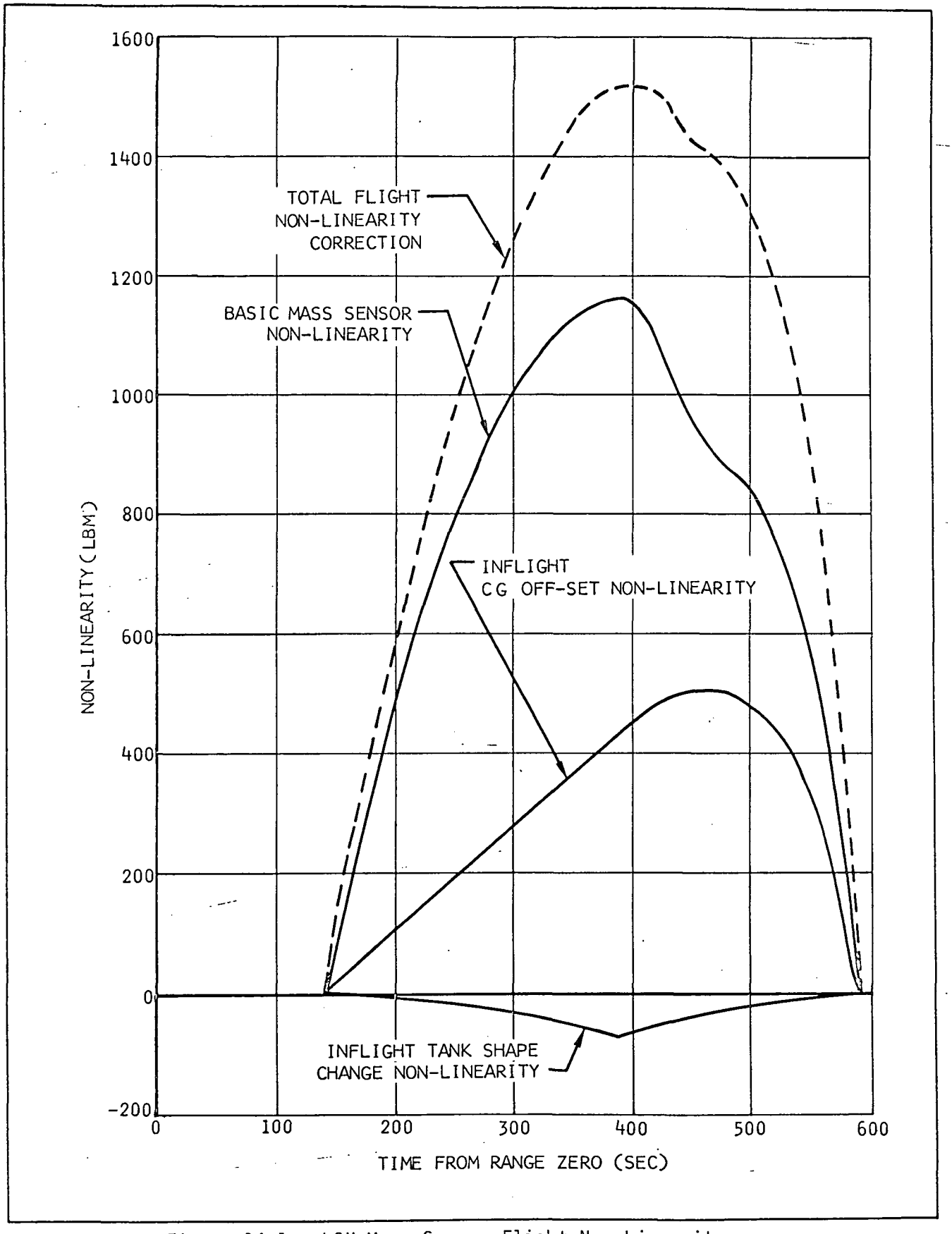


Figure 14-1. LOX Mass Sensor Flight Non-Linearity

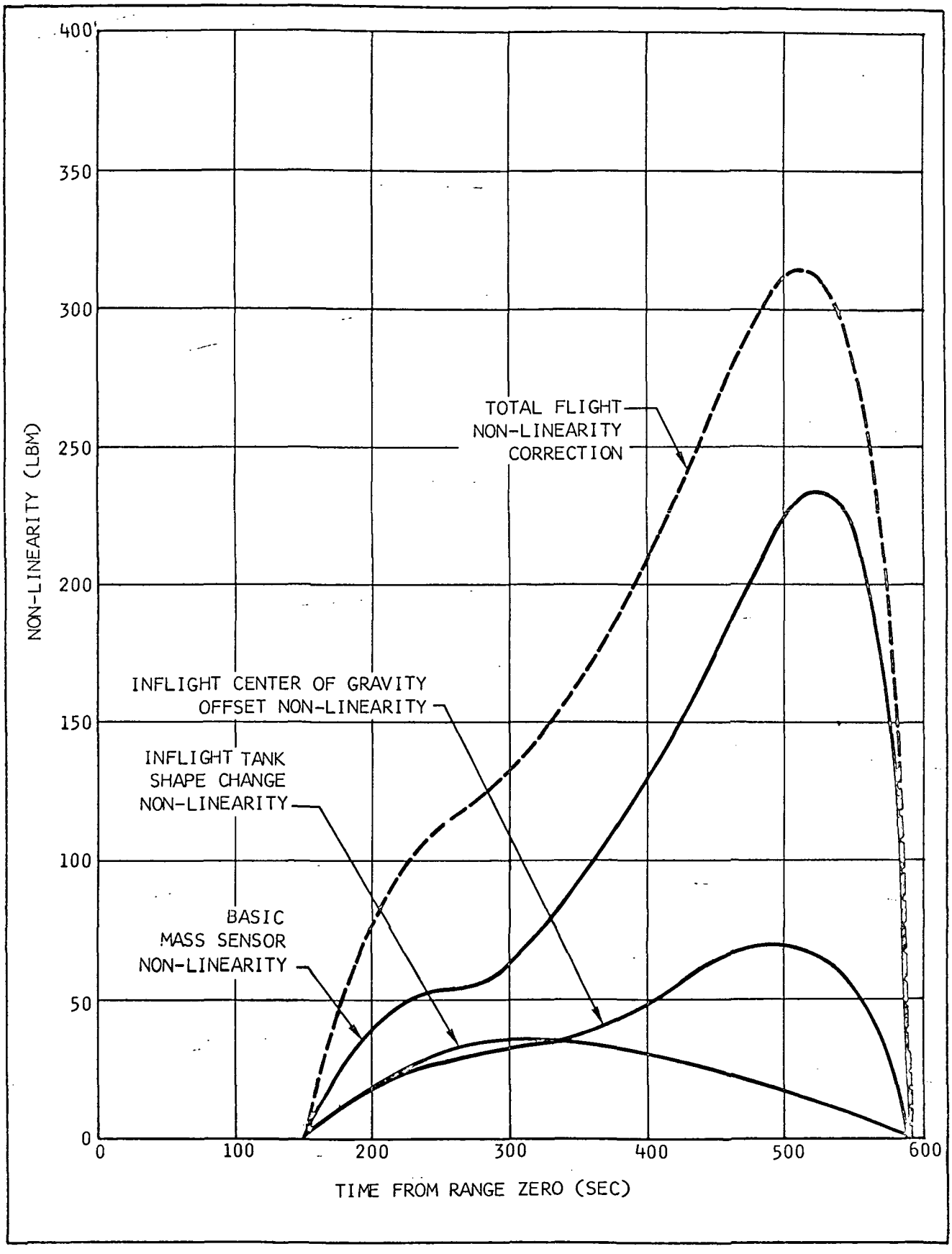


Figure 14-2. LH2 Mass Sensor Flight Non-Linearity

24 October 1966

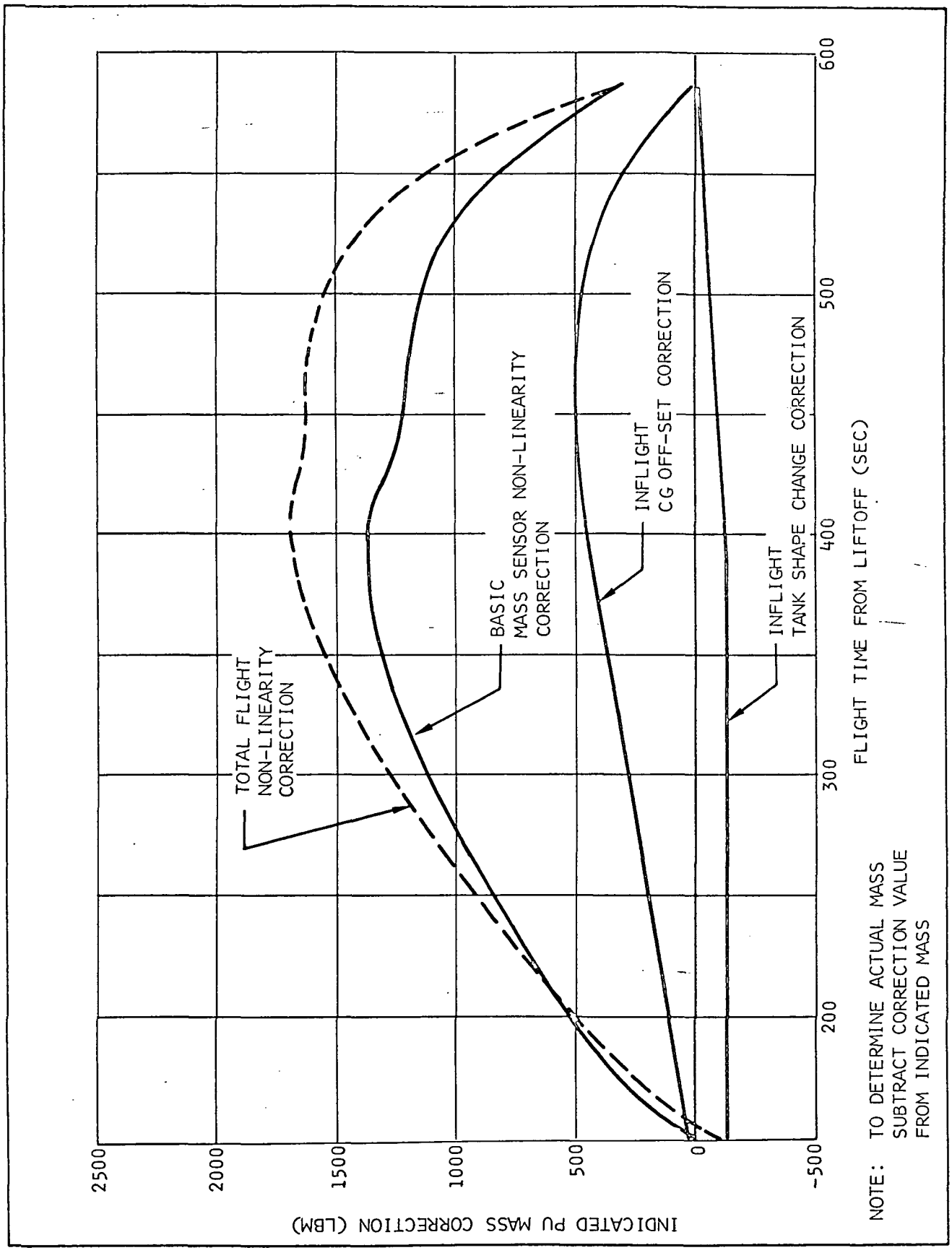


Figure 14-3. LOX Indicated PU Mass Correction

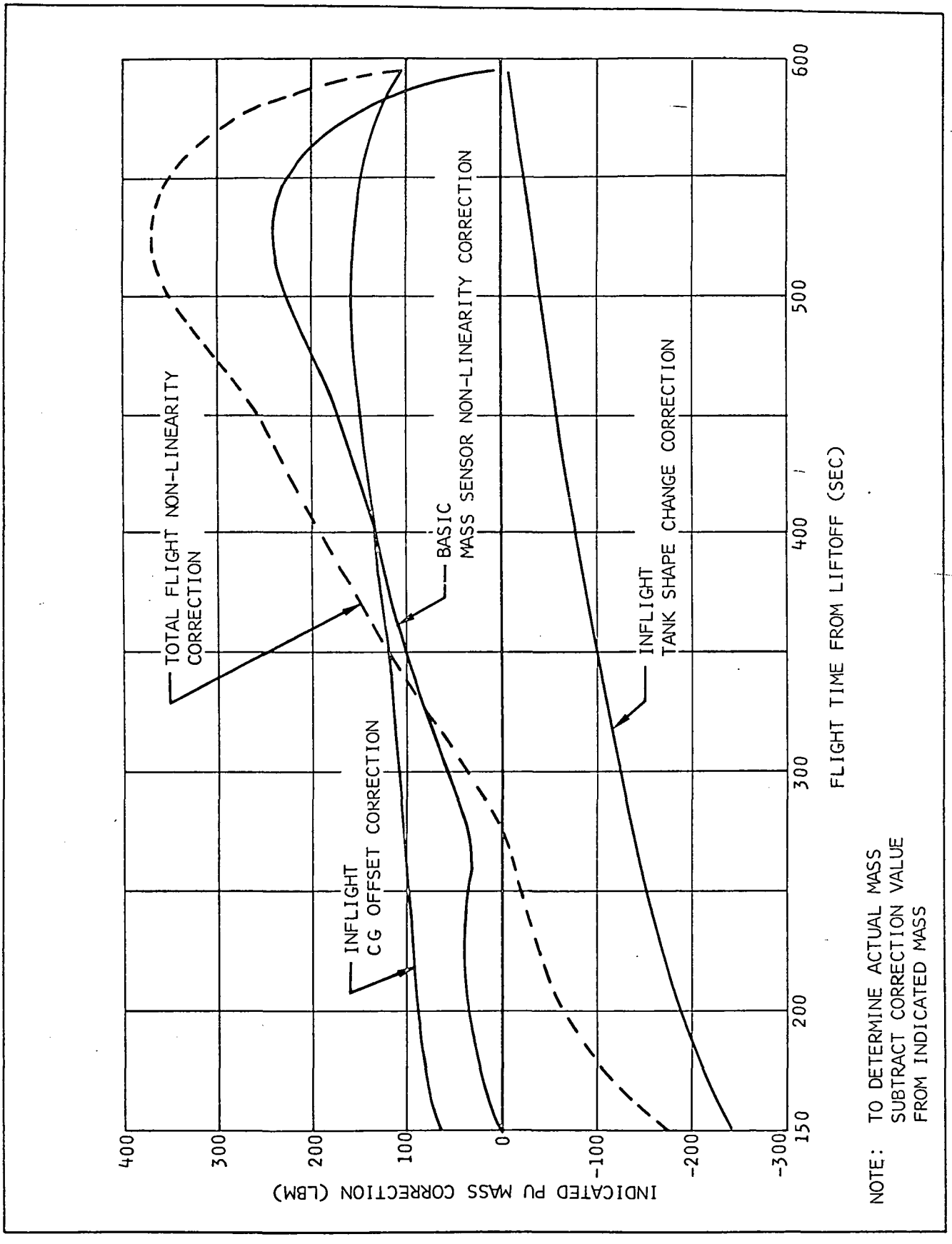
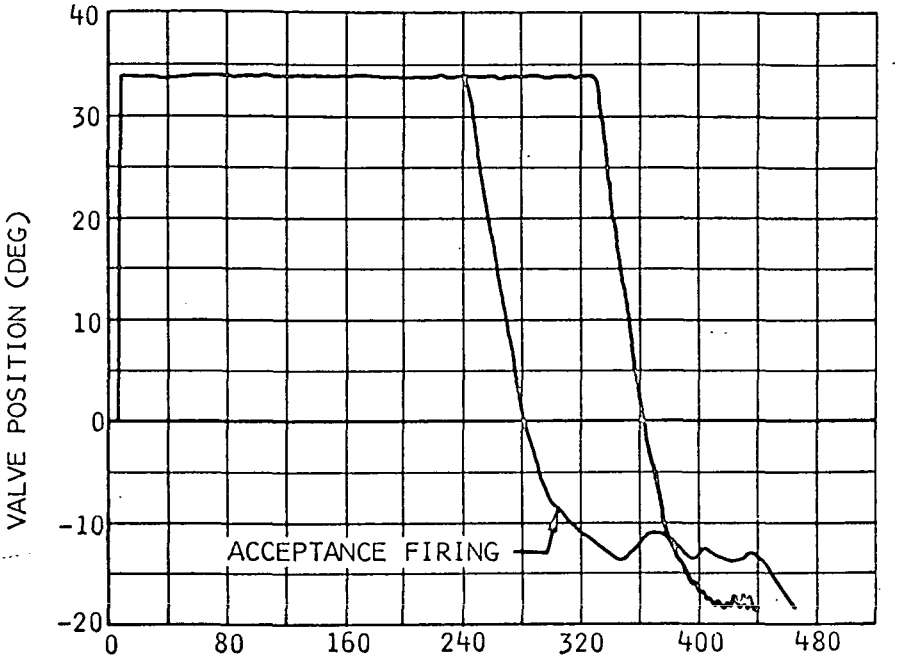


Figure 14-4. LH2 Indicated PU Mass Correction



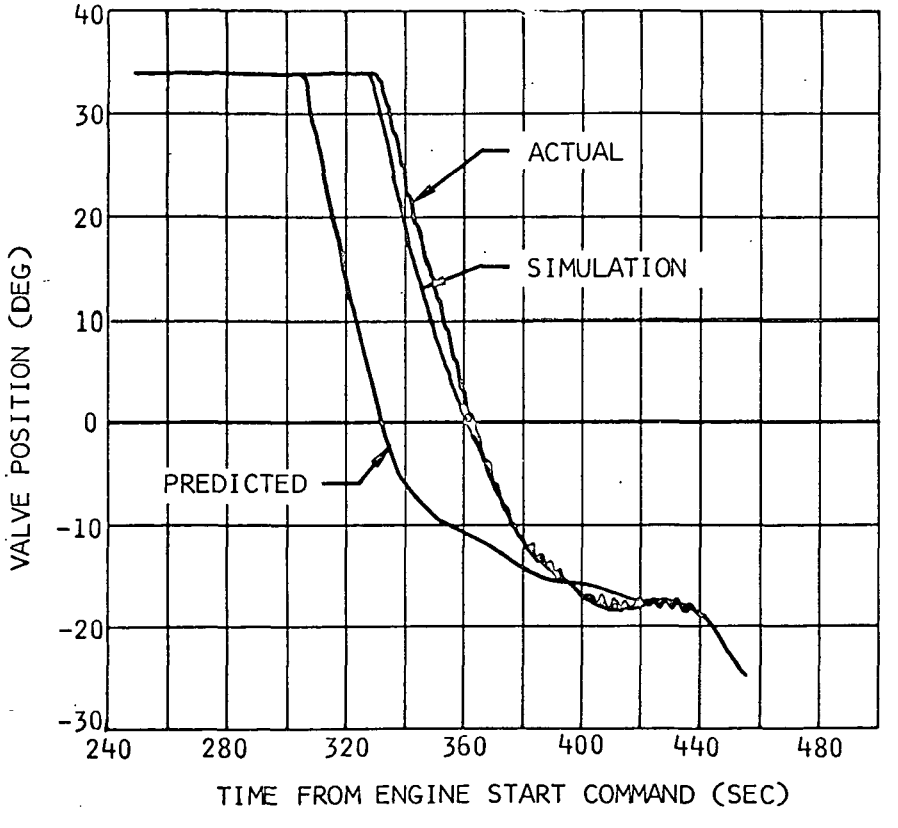


Figure 14-5. PU Valve Position

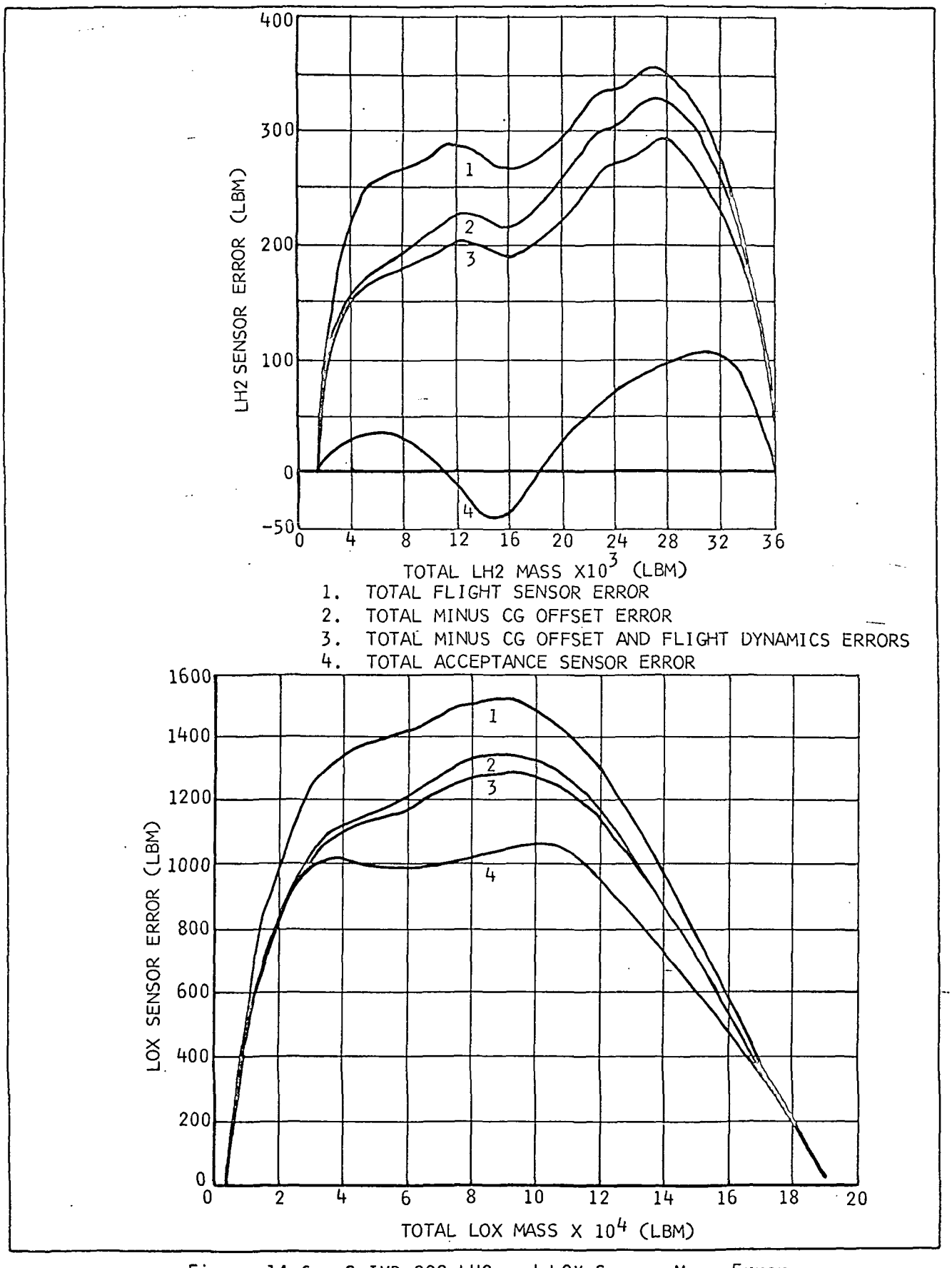
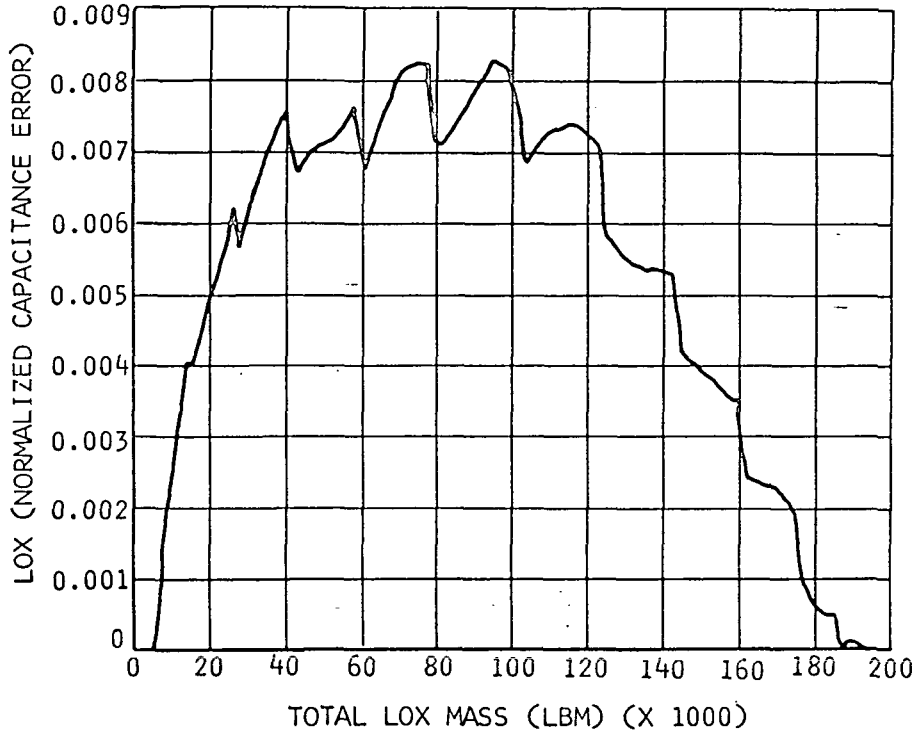


Figure 14-6. S-IVB-202 LH2 and LOX Sensor Mass Error

24 October 1966



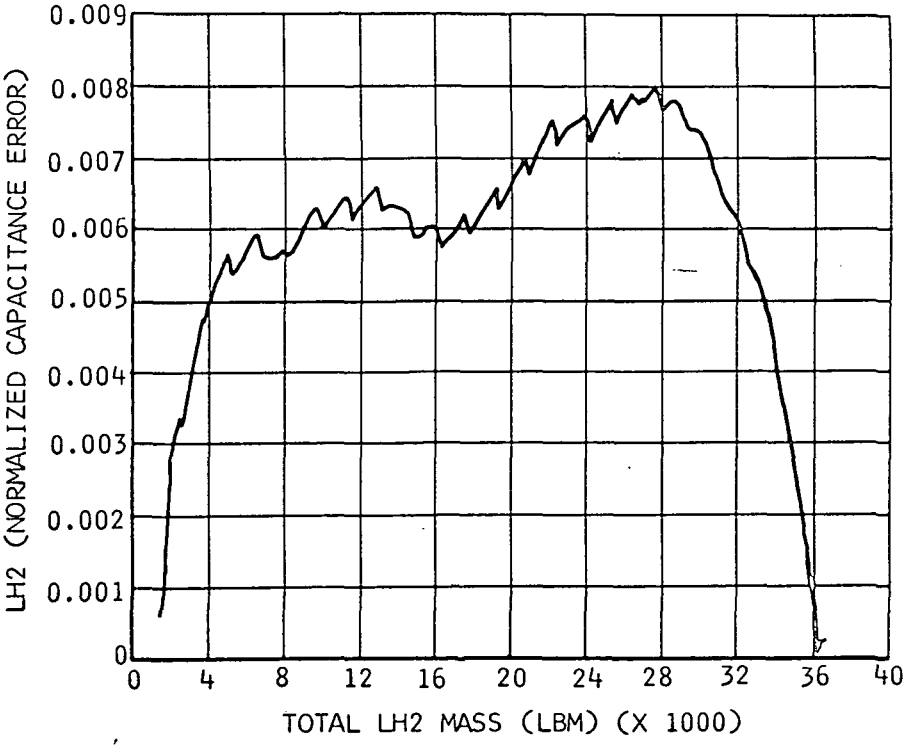


Figure 14-7. S-IVB-202 LOX and LH2 Sensor Capacitance Error

24 October 1966

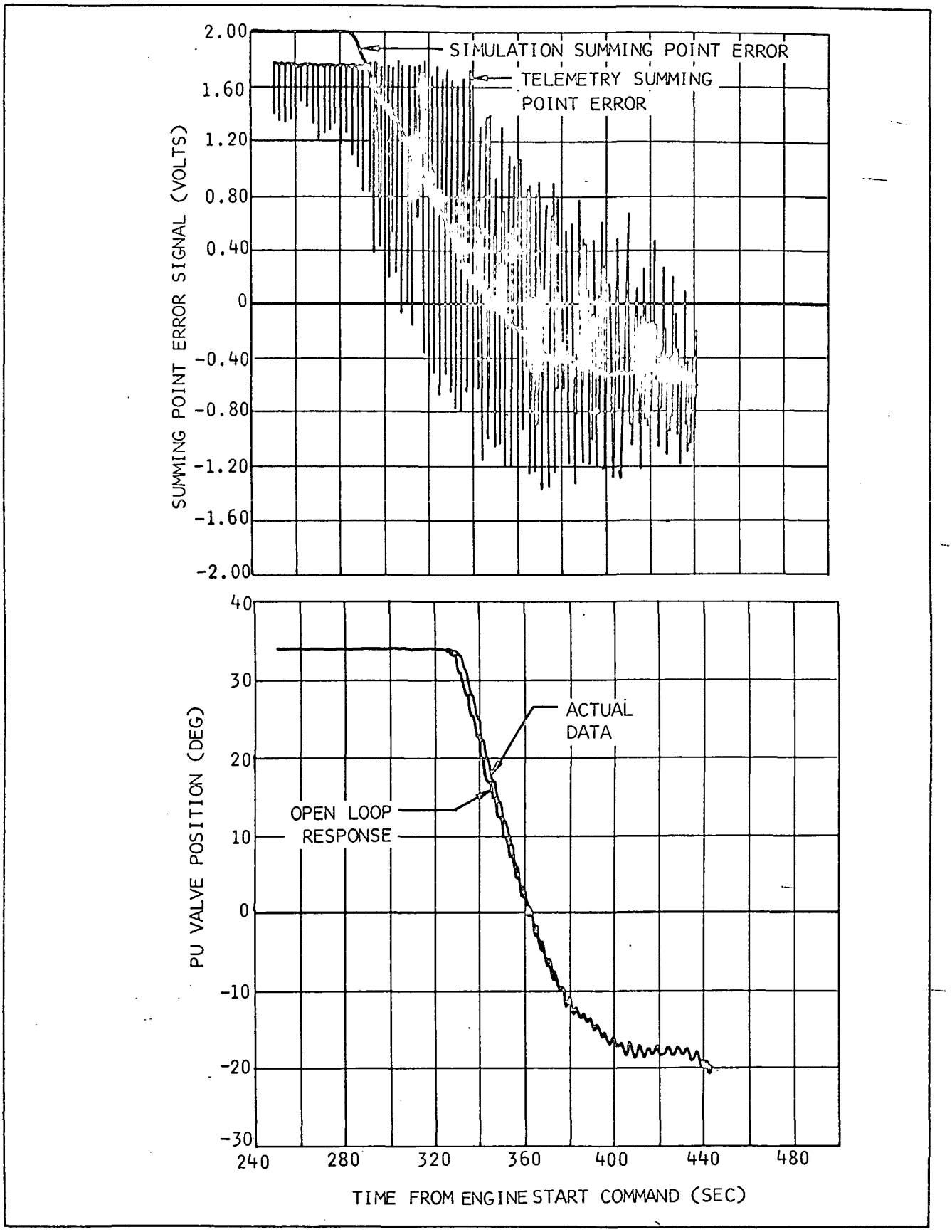


Figure 14-8. PU Error Signal and Valve Response

24 October 1966

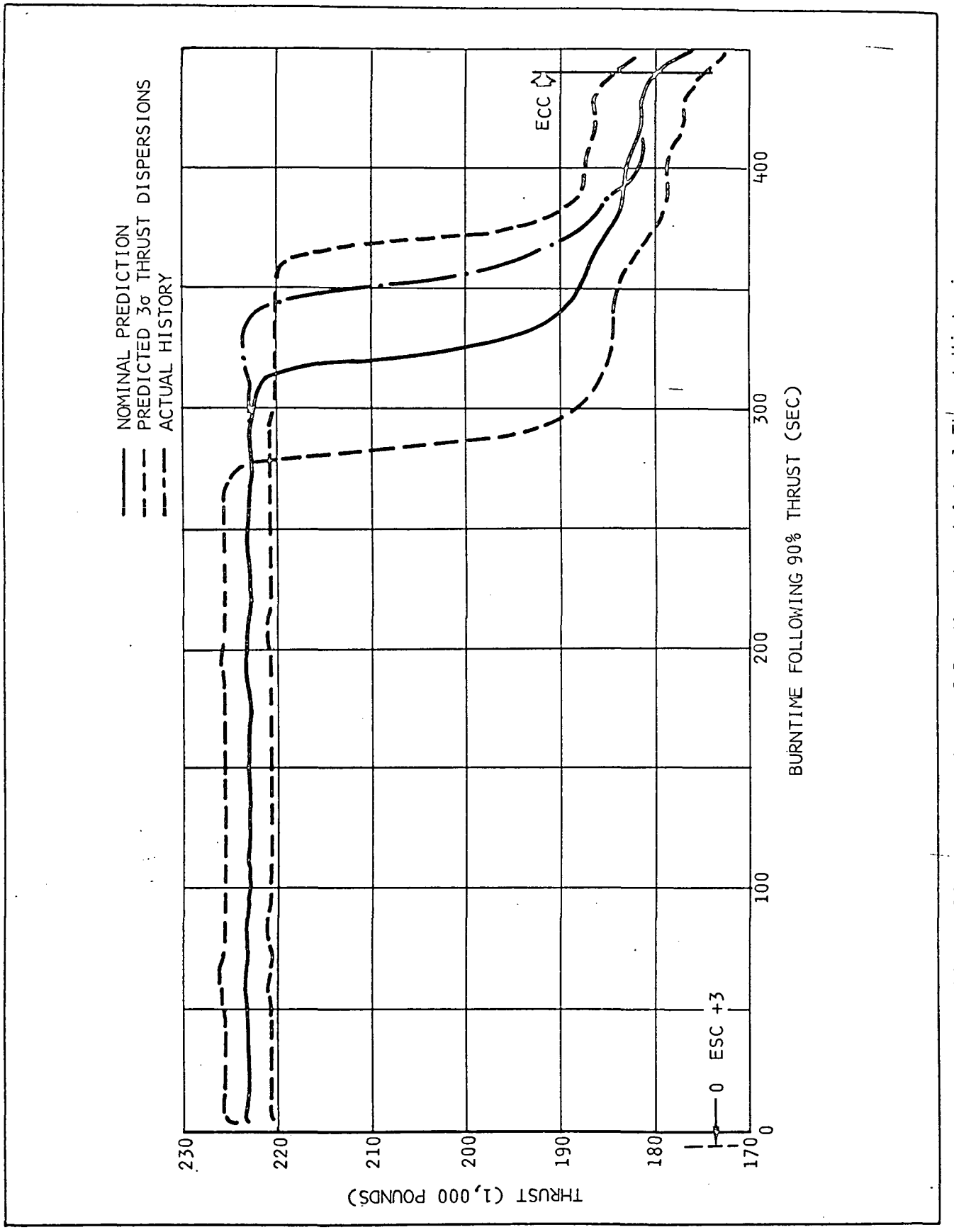


Figure 14-9. Comparison of Predicted and Actual Thrust Histories

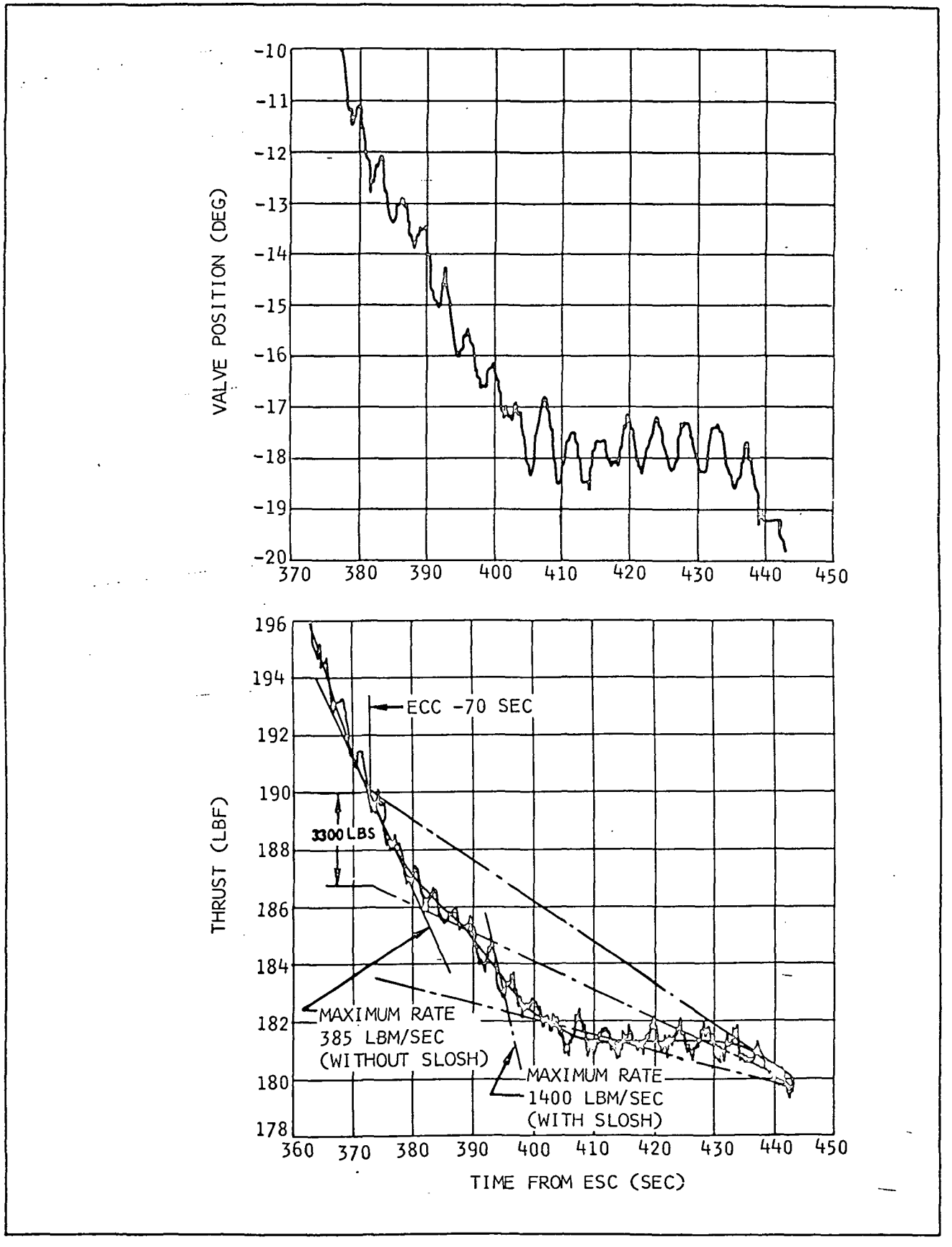


Figure 14-10. Thrust Response to PU Valve Position

24 October 1966

15. S-IB/S-IVB SEPARATION

Separation of the S-IVB stage from the S-IB stage was accomplished satisfactorily within the desired time period. First axial motion between the stages occurred 0.06 sec after the Separation Command. Complete separation was accomplished 1.032 sec after the Separation Command. S-IB and S-IVB relative motion utilized 5.8 in. of the available 83 in. of lateral clearance. Substantial S-IB yaw angular velocities were initially produced by uneven retrorocket plume impingement caused by high performance of two retrorockets. The yaw angular velocity thus achieved, had no detrimental effect on stage separation. After complete separation, a case burn through of the retrorocket located between fin planes II/III and early thrust termination of the retrorocket located between fin planes I/II produced a substantial increase in yaw and roll angular velocity.

15.1 Separation Distance

Complete separation of the S-IVB stage occurs when the S-IVB stage engine thrust chamber clears the S-IB stage separation plane. The axial distance required for complete separation is 217 in. and the lateral clearance available is 83 in. (when the S-IVB engine is centered). Times of events significant to the S-IB/S-IVB separation are listed in table 15-1.

From extensometer and acceleration data the time of first axial motion and the axial separation history were reconstructed. Figure 15-1 contains the predicted separation history and the actual separation history reconstructed from extensometer data. The faster than predicted separation completion time was caused by higher than predicted total retrorocket thrust and lower than predicted total H-1 engine tailoff thrust. Relative velocities of the S-IB and S-IVB are shown in figure 15-2.

15.2 Stage Accelerations and Angular Velocities

The actual longitudinal accelerations of the S-IB and S-IVB stages are shown in figure 15-3. The reconstructed S-IVB stage acceleration was

obtained from the accelerometer data recorded on the inflight tape recorder. The S-IB stage acceleration was derived using extensometer, H-1 engine thrust, and retrorocket thrust data. Angular velocities and lateral accelerations for the S-IVB stage remained small during separation. S-IB pitch, yaw, and roll angular velocities are shown in figure 15-4. Yaw angular velocity exhibited a substantial positive change (nose right) during separation. A reconstruction of this angular velocity data is discussed in paragraph 15.3.2. The values for all S-IB and S-IVB stage angular velocities at Separation Command were less than the design maximum rates of 1 deg/sec.

The maximum S-IVB angular velocities measured during separation were 0.40 deg/sec nose down in pitch, 0.62 deg/sec nose right in yaw, and 0.21 deg/sec counterclockwise, looking forward, in roll. S-IB and S-IVB stage lateral accelerations remained essentially zero before and after separation.

15.3 Relative Lateral Motion

15.3.1 Clearance Distance

The lateral clearance used during separation was 5.8 in. Preflight studies indicate the probability of exceeding this lateral displacement is 0.23 in. as shown in figure 15-5. The path of the S-IB interstage lip relative to the S-IVB aft interstage and J-2 engine during separation is shown two-dimensionally in figure 15-6. During separation, a point on the S-IVB engine thrust chamber between fin planes I and II utilized 5.8 in. of the available 83 in. of lateral clearance.

15.3.2 Effect of Retrorocket Performance on S-IB Stage Motion

The observed motion of the S-IB stage during the separation process can be explained by observed performance characteristics of the retrorockets and a casing burn through of retrorocket II/III. Evaluation of the telemetered S-IB angular velocity and translational acceleration data verifies the conclusion reached in paragraph 9.2 that the retrorocket

between fin planes II/III burned through its casing. This data also verifies the magnitude of retrorocket III/IV and IV/I plume impingement force, determined by flow field analysis (paragraph 24.2.2).

The sharp inflections in roll and yaw angular velocities at RO +145.62 sec, are coincident with the rapid loss of retrorocket II/III chamber pressure (figure 15-4). During this period the pitch and yaw translational acceleration remained negligible.

Figures 15-7 and 15-8 present a reconstruction of the observed yaw and roll angular velocities. It is believed that the retrorocket performance characteristics caused the majority of the observed angular velocity changes. Following retrorocket ignition and prior to retrorocket II/III burnout the high thrust of retrorockets III/IV and IV/I produced an unbalanced side force due to unbalanced plume impingement which caused a 1.0 deg/sec change of S-IB yaw angular velocity. Retrorocket II/III lost chamber pressure abnormally at RO +145.62 sec, and retrorocket I/II had an early but normal burnout 0.1 sec later. Retrorockets III/IV and IV/I burned for 0.1 sec longer than retrorocket I/II. Considering only the staggered burnout times, no yaw or roll rate increase would have been expected following RO +145.65 sec since the unbalanced yaw moments caused the thrust of retrorockets I/II, III/IV and IV/I would have been opposed by an equal unbalanced moment produced by their plume impingement on the interstage, as shown in figure 15-7. If retrorocket II/III had burned out normally there would have been no increase in roll angular velocity at RO +145.62 sec. Given the probability of retrorocket II/III case burn through, the direction and magnitude of the burn through thrust was calculated. It was found that over the 0.3 sec interval following the time of assumed burn through, an average force of 3,400 lbf in a direction determined to be $\theta = 2$ deg, in figure 15-9, would yield a near exact match of the observed change in roll and yaw angular velocity.

The burn through angle indicated in this figure is not entirely consistent with observed data since only 0.5 deg/sec change in pitch angular velocity was observed during this interval and the calculated burn through angle and force would indicate that the pitch angular velocity

should have changed 0.8 deg/sec. It is believed that this inconsistency could be explained by a side force due to burn through impingement, which was not considered in the analysis. It is believed that an analysis giving a detailed consideration of this impingement would yield a burn through angle somewhere in the outboard retrorocket quadrant towards fin plane II (figure 15-9).

TABLE 15-1
S-IB/S-IVB SEPARATION SEQUENCE OF EVENTS

EVENT	ACTUAL TIME FROM RANGE ZERO (sec)	TIME FROM SEPARATION COMMAND (sec)	
		ACTUAL	PREDICTED
S-IB stage OECO	143.47	-.80	-.80
Ullage rocket ignition	144.023	-.247	-.20
Separation Command	144.27	0	0
S-IB retrorocket ignition	144.27	0	0
Ullage rocket thrust to 75%	144.28	.01	.01
Retrorocket thrusts to 10%	144.32	.05	N/A
First axial motion	144.33	.06	N/A
Retrorocket thrusts to 90%	144.34	.07	N/A
Separation complete	145.302	1.032	-1.00
S-IVB stage ESC	145.624	1.354	1.40
J-2 engine at 90% thrust (defined as P_c = 618 psi)	149.126	4.856	4.80

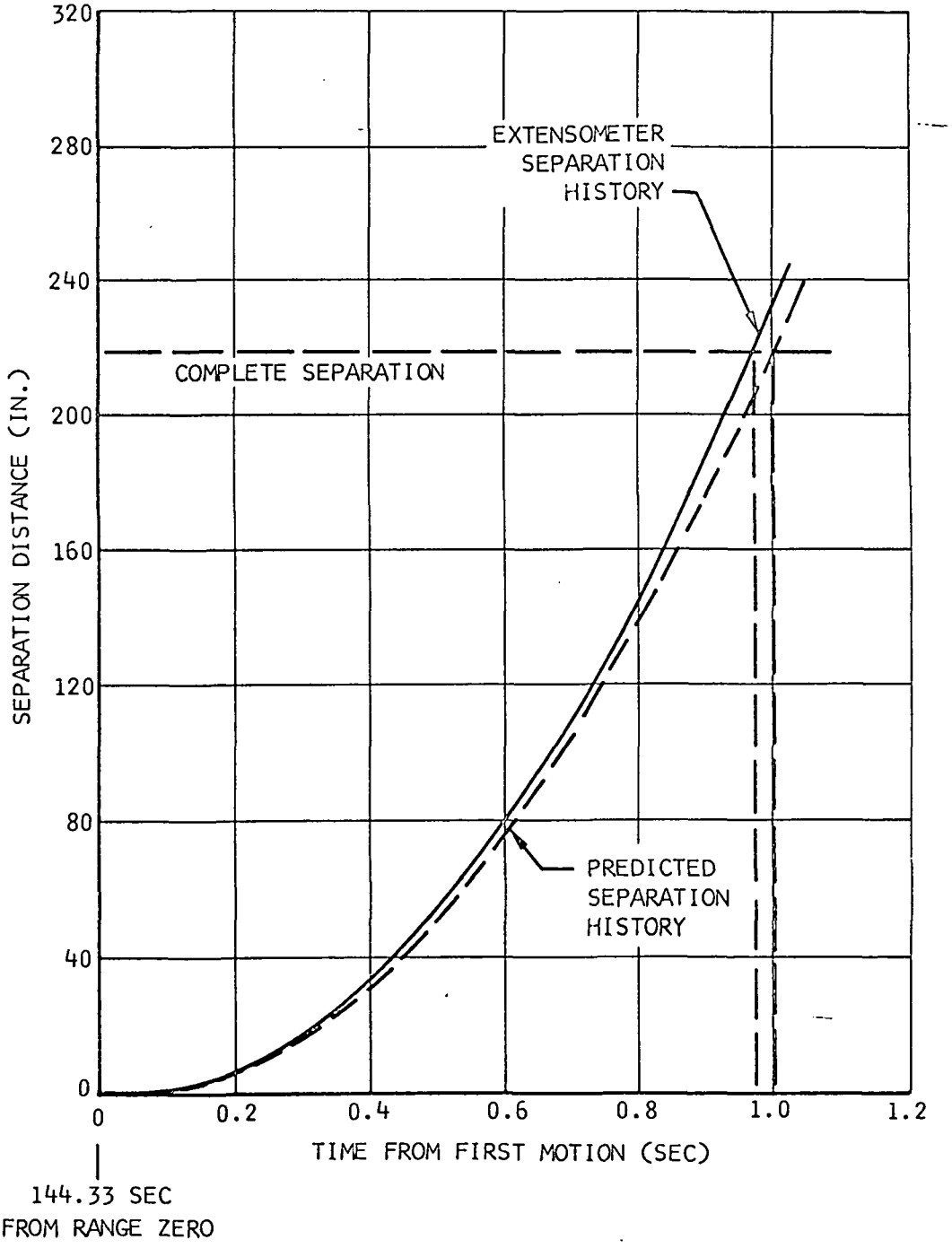


Figure 15-1. S-IB/S-IVB Separation History

24 October 1966

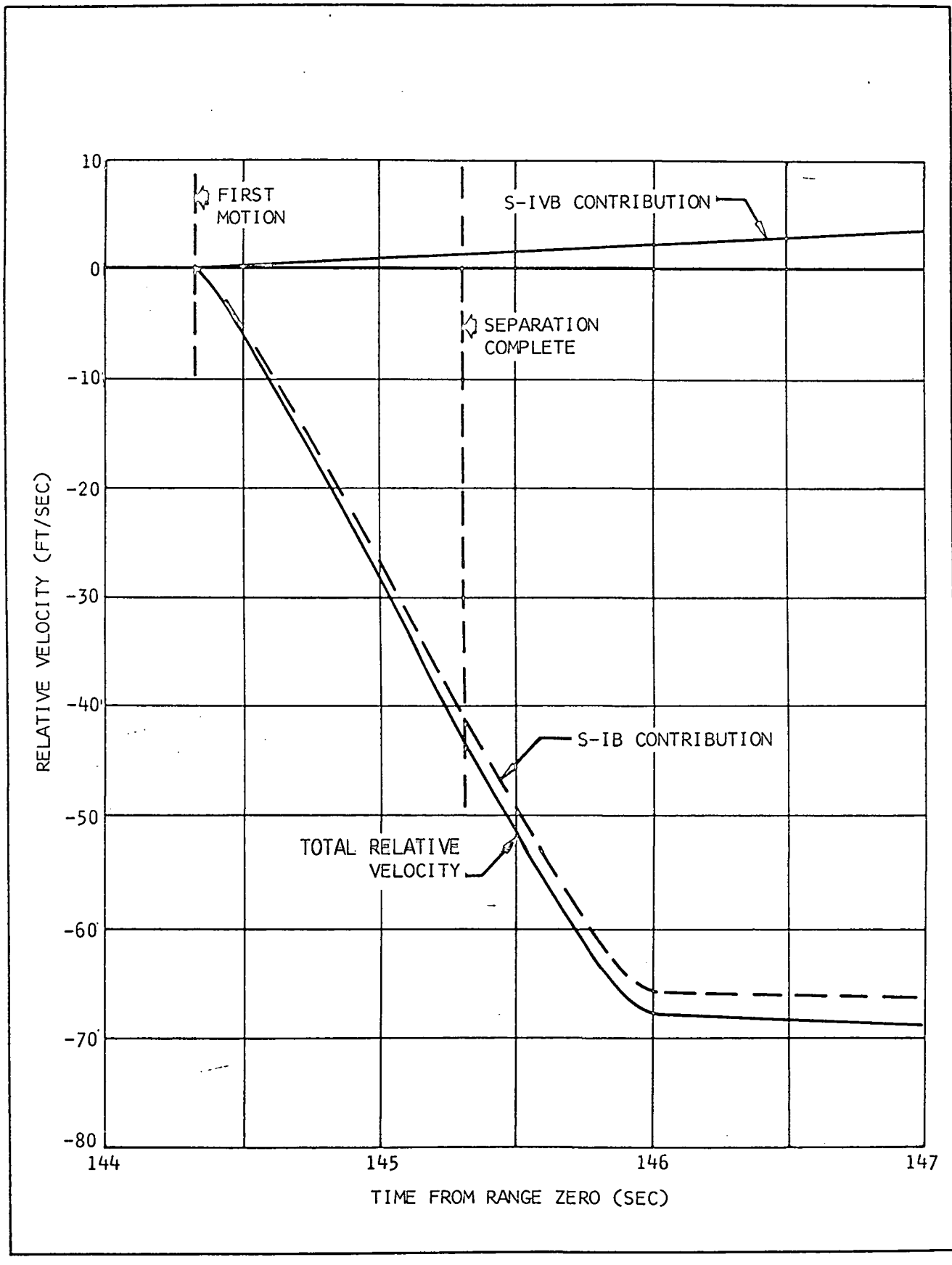


Figure 15-2. S-IB/S-IVB Relative Velocity History

24 October 1966

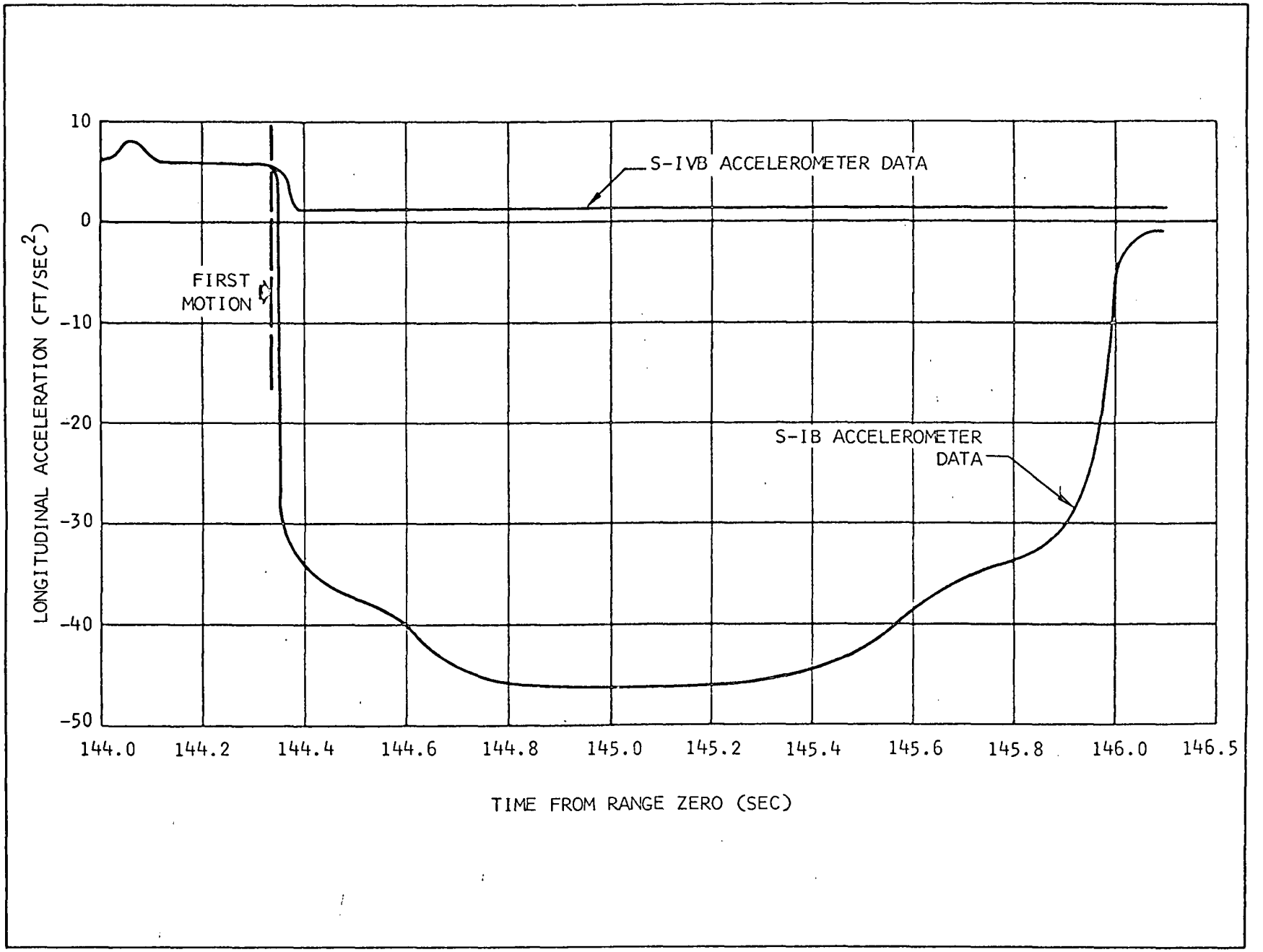


Figure 15-3. S-IB/S-IVB Separation Longitudinal Acceleration

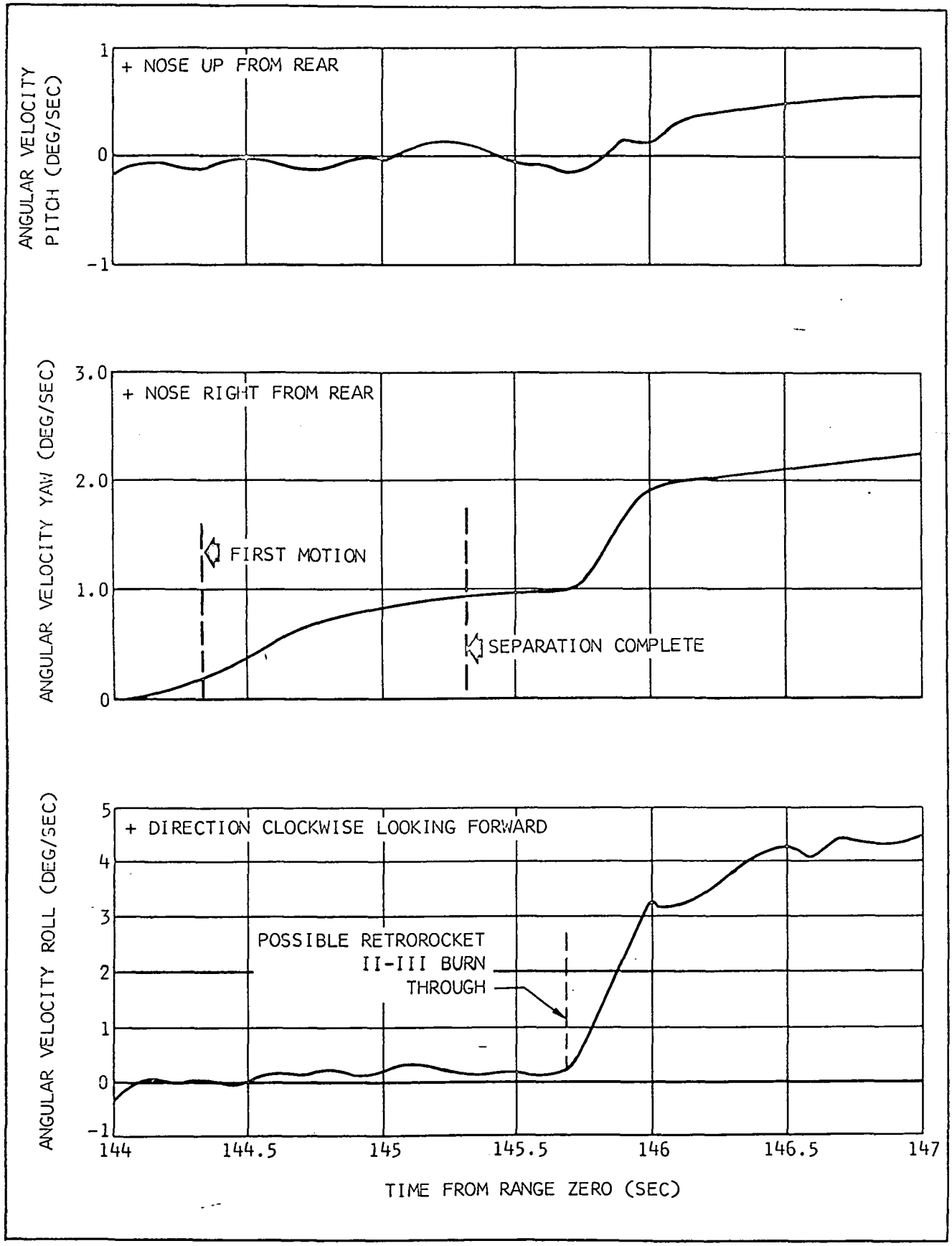


Figure 15-4. S-IB/S-IVB Separation, S-IB Pitch, Yaw and Roll Angular Velocity

24 October 1966

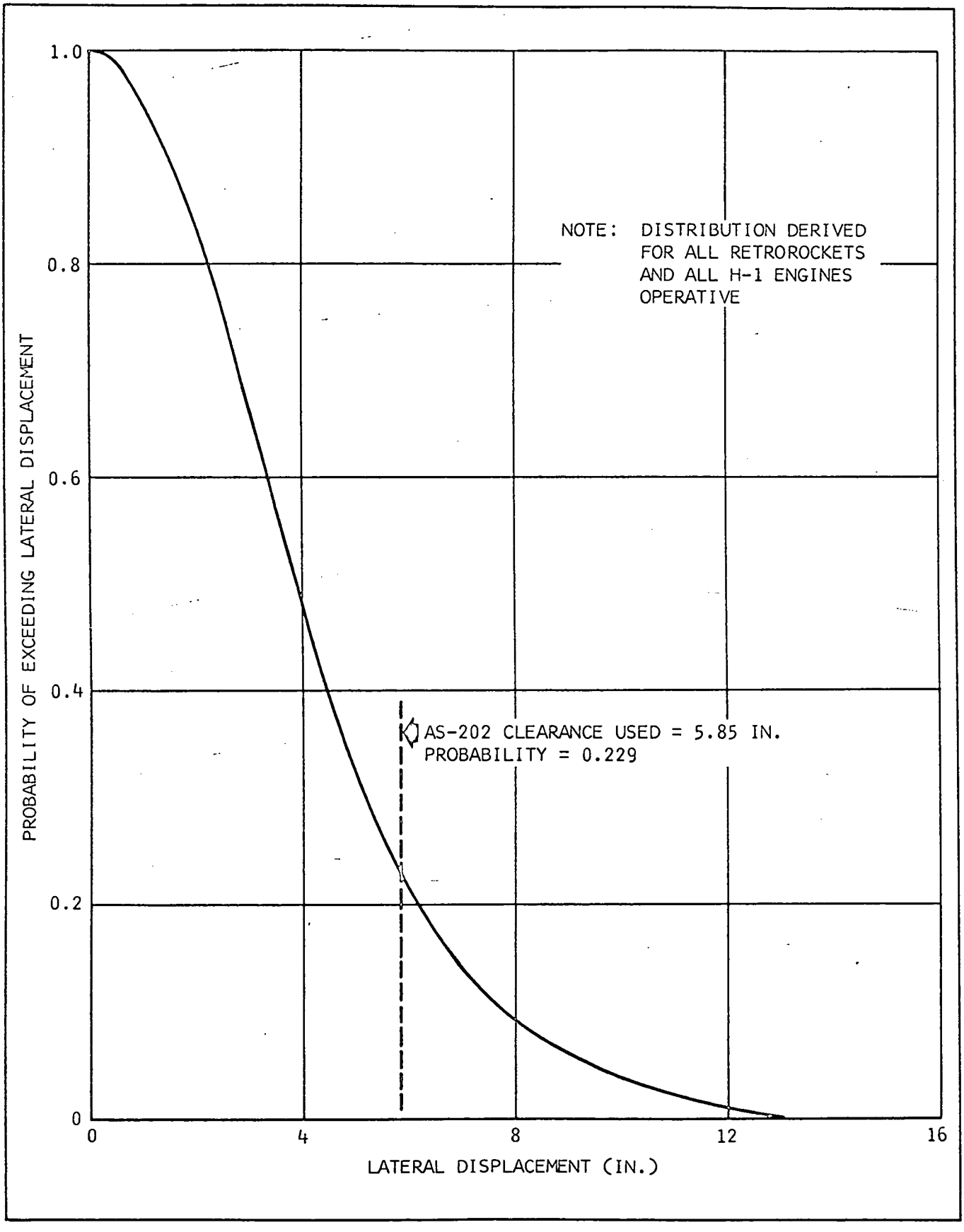


Figure 15-5. Probability of Lateral Displacement Exceeding a Specified Value

24 October 1966

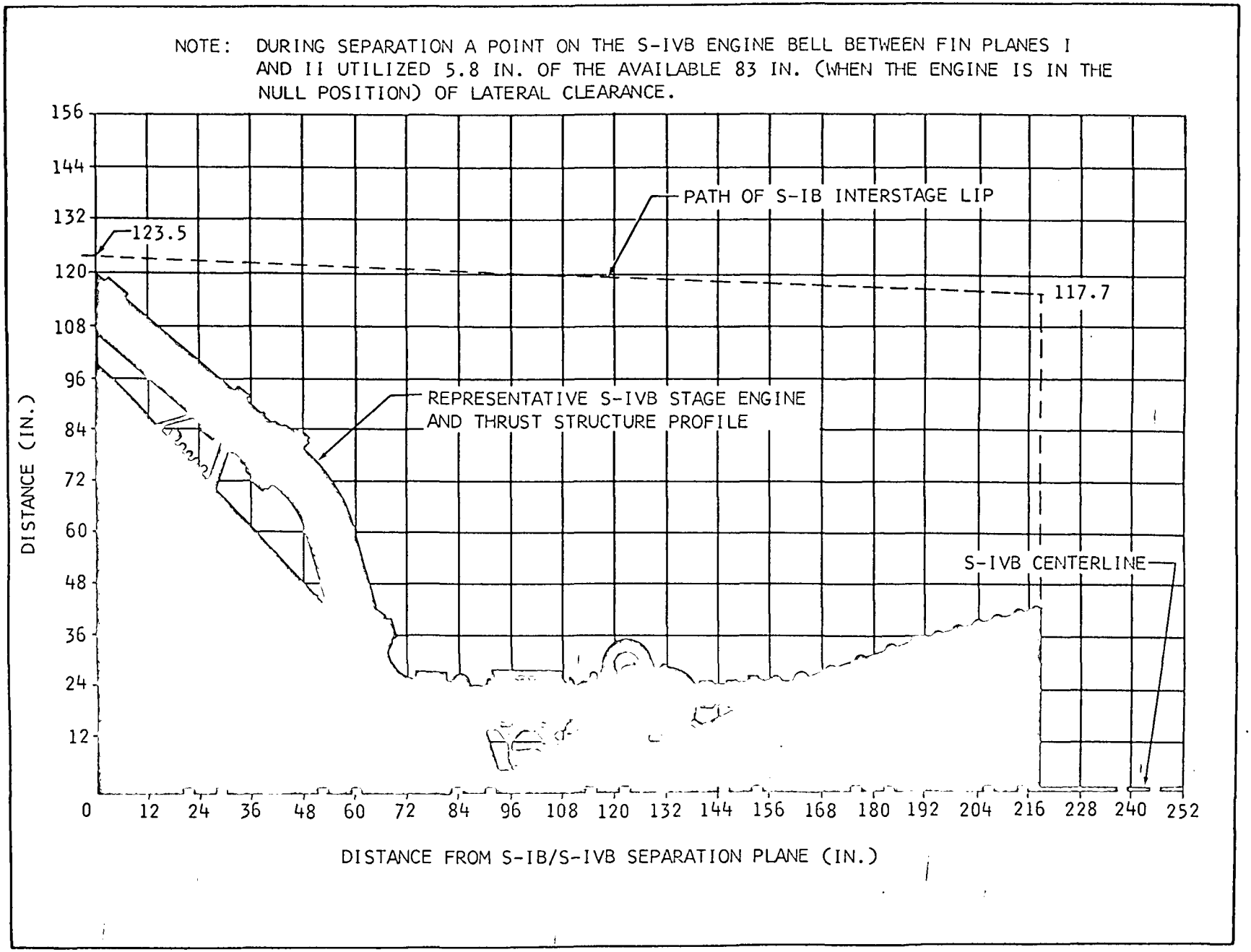


Figure 15-6. S-IB/S-IVB Separation Distance

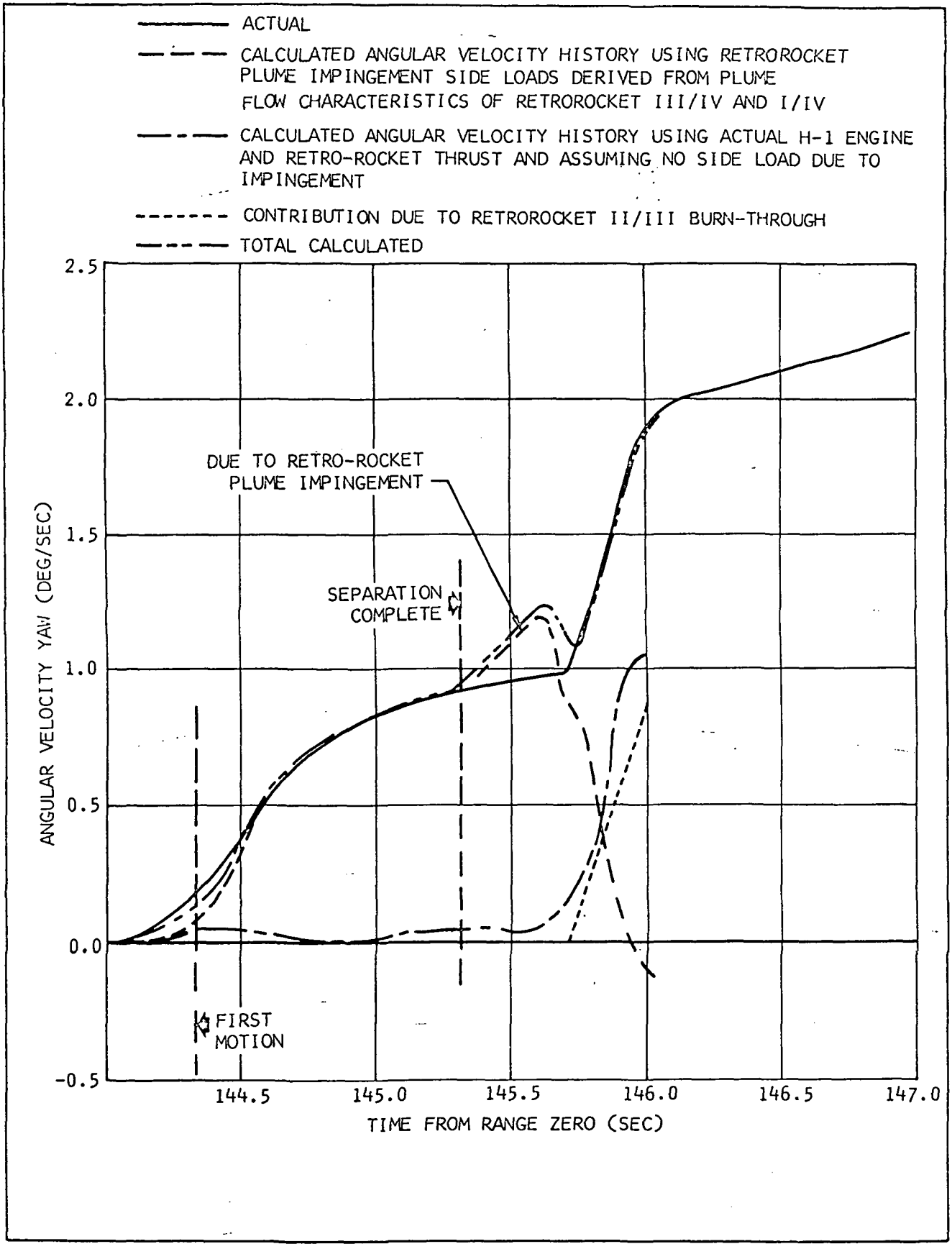


Figure 15-7. S-IB/S-IVB Separation, S-IB Yaw Angular Velocity

24 October 1966

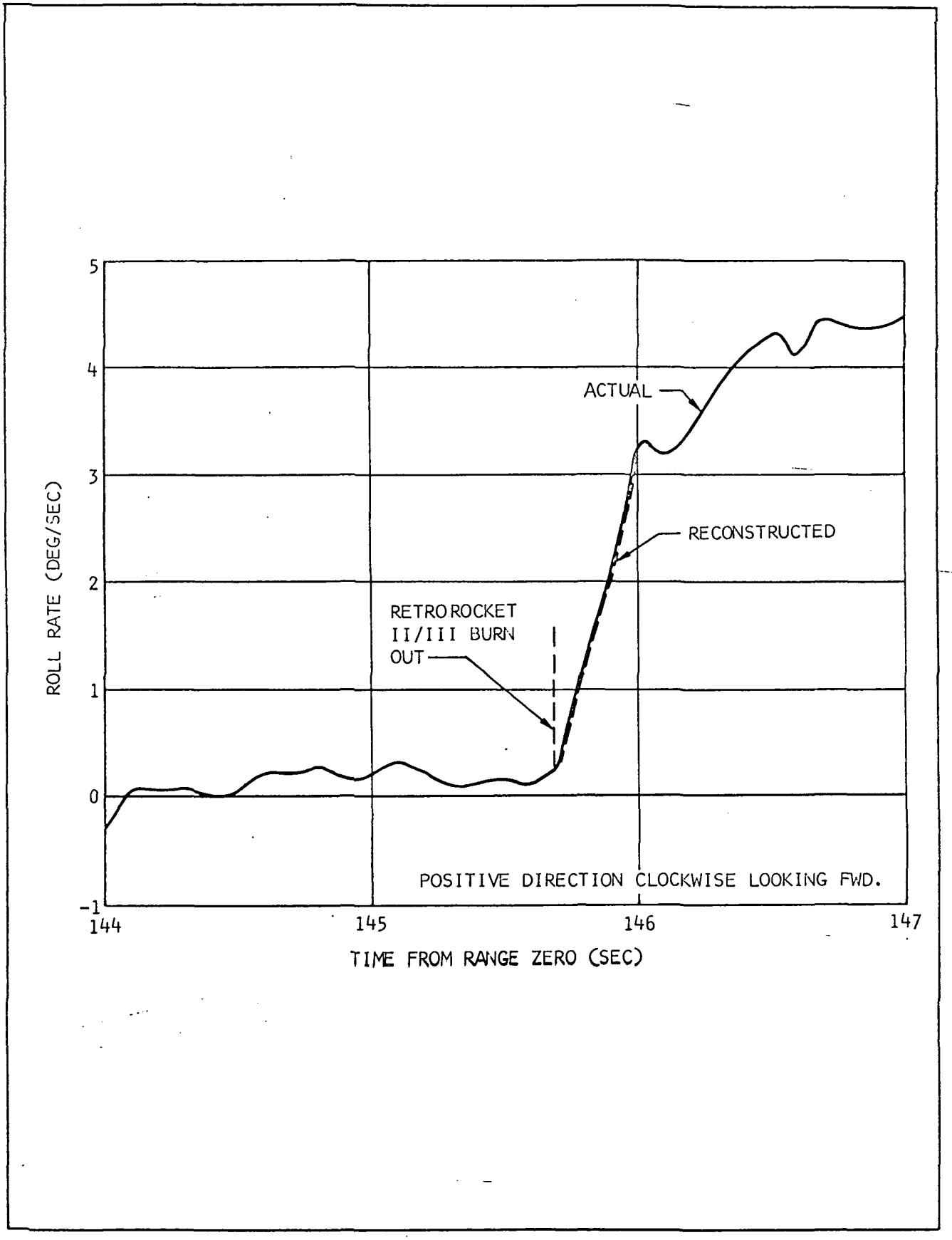


Figure 15-8. S-IB Roll Rate Actual and Reconstructed

24 October 1966

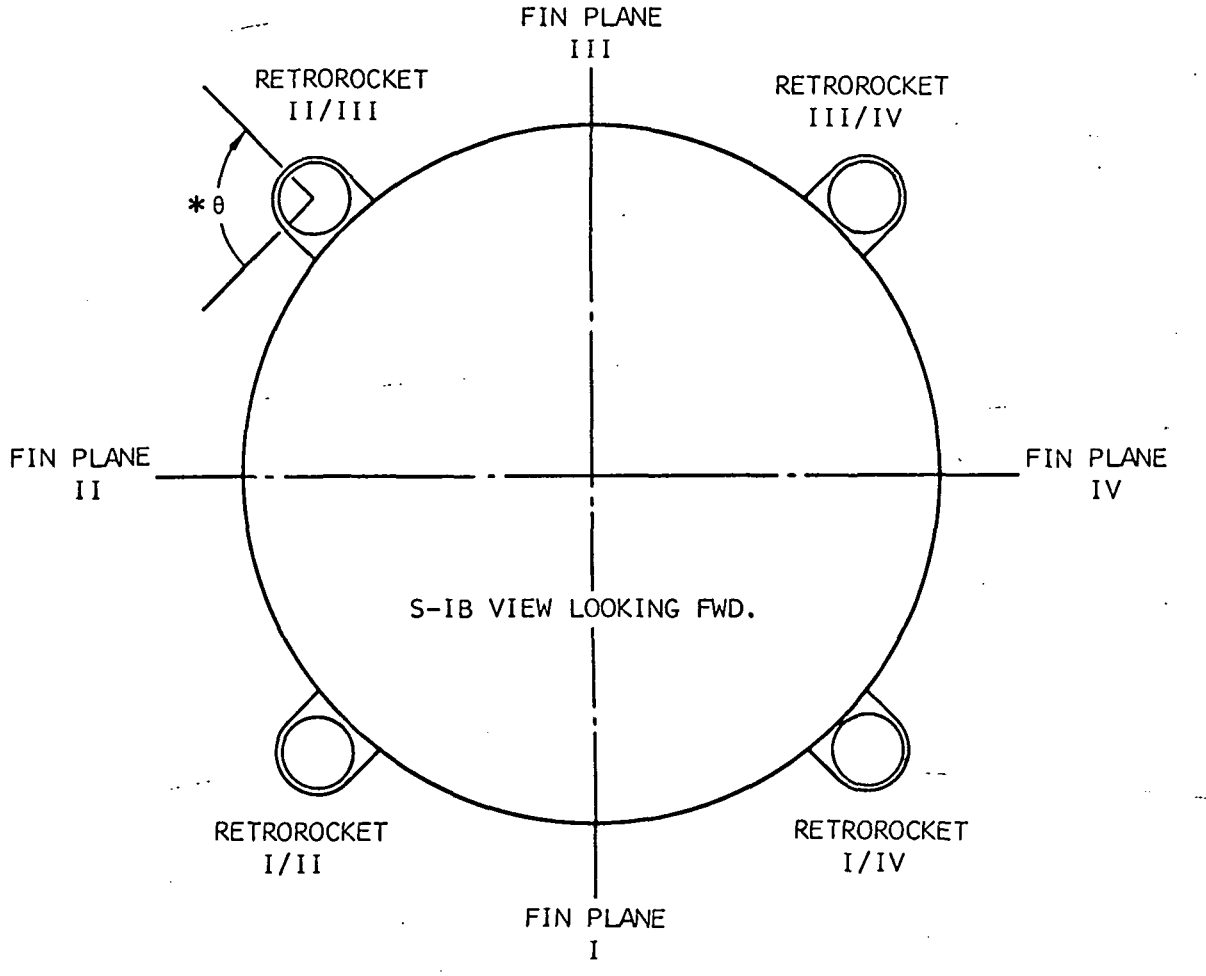


Figure 15-9. Retrorocket Positions

24 October 1966

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p. 240

16. DATA ACQUISITION SYSTEM PERFORMANCE

The objective of the data acquisition system is to gather, condition, and transmit the data required to evaluate the stage environment and the systems performance during flight. The measurements collected are specified in DAC Drawing No. 1B43555, AA Change, Instrumentation Program and Components List (IPCL). The function of gathering and conditioning the data is provided by the instrumentation system, and the telemetry system provides the transmission capability. The final data is processed to conform with the requirements of the measurement request drawings.

The following table presents the various measurement groupings which resulted from the evaluation of the S-IVB-202 stage telemetered data from the standpoint of data usability by the requesting design sections. This tabulation does not include instrumentation system performance groupings resulting from evaluation conducted on a design requirement basis. Thus, a measurement failure observed outside the period of interest specified by the requesting design section would not be classified as a failure in this tabulation. Measurement anomalies from an instrumentation design requirement point of view are presented in paragraph 16.1 and tables 16-1 through 16-3.

Measurements Assigned per IPCL	472
Measurements inoperative due to stage configuration	-2
Checkout measurements	-19
Measurements monitored by S-IB stage	-6
Measurements failing prior to automatic sequence	-2
Measurements deleted prior to countdown	-8
Measurements active for flight	435
Measurement failures	2
Measurement efficiency	99.54%

The measurement failures listed are S0016 - Strain - Axial Forward Skirt, No. 1 which failed to provide usable data throughout the flight due to temperature effects and C0134 - Temp - LH2 Pump Discharge, which was off-scale high throughout the flight. The range of measurement C0134 was changed for the S-IVB-203 flight and satisfactory data was obtained.

16.1 Instrumentation System Performance

The performance of the instrumentation system was very good throughout the flight and sub-orbital coast period. Although a few transducers failed and there were some other transducer problems, there were no system failures. Table 16-1 lists the S-IVB-202 measurements by category. The transducer failures and problems are presented in detail in tables 16-2 and 16-3. Measurements C0077, C0078 and M0024 failed at RO +610 sec, the time of service propulsion system (SPS) firing. These measurement failures appear unrelated because each were at different locations. Their instrumentation networks were on different panels and several other measurements would seem likely to have failed if the failure were caused by external means. However, the possibility of engine plume impingement or particle impact caused by the SPS firing is being considered for these failures.

16.2 Telemetry System

The overall telemetry system performed satisfactorily. No discrepancies were observed. Detailed explanations of each subsystem are given in further detail below. RF and antenna system performance is presented in table 16-4.

16.2.1 Pulse Amplitude Modulation System

The proper performance of the pulse amplitude modulation (PAM) system was verified by intelligible data from all channels. All reference data were within proper tolerance levels. Proper PAM format was sent to the pulse code modulation (PCM) system for satisfactory PCM formatting. No loss of synchronization of the 270 multiplexer with the PCM unit was observed.

16.2.2 Pulse Code Modulation System

The PCM system performance was as anticipated. The PAM signal from the 270 multiplexers was properly formatted by the PCM unit. All reference levels were within system tolerances. The PCM/PAM comparison data was well within acceptable limits.

16.2.3 Frequency Modulation System

The frequency modulation (FM) system performed as expected. All subcarrier frequencies were observed to be within acceptable tolerances. System calibration was successfully accomplished at the times commanded by the sequencer (see section 4 for exact times). No abnormal characteristics were observed in the subcarrier oscillator calibration frequency and drift characteristics during the mission.

16.2.4 Single Sideband System

The single sideband system performance was normal. Data was verified from all channels. The calibration signal was observed at the proper times (see section 4 for exact time). The 245 multiplexer properly time shared its multiplexer signals. No loss of the pilot tone was observed.

16.2.5 Inflight Tape Recorder Assembly

The inflight tape recorder performance was very good. The tape recorder recorded all data during blackout and played it back on command.

The tape recorder was commanded to record at RO +138 sec and recorded for 27.3 sec. This time covered the period of separation and ullage rocket jettison. The tape recorder was commanded to play back at RO +627 sec and played back for 27.6 sec. This data was acquired at the Tel 2 and Antigua stations.

The tape recorder required 1.28 sec to attain its proper speed after the initiation of the "playback" command. The wow & flutter characteristic was not evaluated because the data was not available; however, the playback data was observed to be acceptable for engineering evaluation.

16.2.6 Calibration Assembly

The calibration assembly performed all inflight calibrations as commanded by the sequencer. All the calibration steps were at the correct levels and the calibration sequencers were in proper synchronization.

The subcarrier oscillator and single sideband calibrations were given at RO +128 sec (pre S-IVB burn), RO +351 sec (during S-IVB burn), and RO +611 sec (post S-IVB burn).

16.2.7 Radio Frequency System

In general the performance of the radio frequency (RF) system was very good throughout powered flight. All outputs from the power amplifiers were above the minimum specified 25 watts. The voltage standing wave ratios were very low and the signal strengths at all ground stations were well above threshold. The performance figures for the RF and antenna systems are presented in table 16-4.

16.2.8 Telemetry Signal Strength

The ground station receiver signal strength data from the flight of S-IVB-202 is somewhat more interesting than equivalent data from prior flights of S-IVB stages due to the unusual maneuvers performed. There was a programmed roll maneuver starting at 100 sec after J-2 engine cutoff. Data review indicates a large pitch maneuver between RO +212 and +280 sec; however, this was not substantiated by guidance data. MSFC feels this indication was the result of an F_1 ionospheric layer effect.

The signal strength data are, in general, quite poor and, therefore, difficult to reivew and correlate. Following is a station-by-station analysis.

16.2.8.1 Tel 2

Signal strength data were pegged at full scale until the elevation angle reached 60 deg, at which time the antenna started to sweep in azimuth (RO +38 sec). The azimuth track was rather coarse initially (probably a high angular rate course track) and appeared to overshoot and overadjust until the azimuth angular velocity slowed enough to permit a finer servo loop (approximately RO +104 sec). Signal strengths were excellent and steady from this point to first stage cutoff.

First stage cutoff caused signal strength drops from about 5K μv to 3K μv with about 500 μv rapid variation evident about these levels. Separation caused signal strengths to drop to a range of about 50 μv to 5K μv with rapid excursions between these values. Ullage rocket ignition caused a loss of data for about 1 sec. Signal strengths then returned to 5K μv. At 60 sec into the S-IVB stage burn, oscillations in signal strength started. The magnitude of these oscillations increased gradually to ±1K μv and decreased to no oscillations in a period of 78 sec.

In general, a broad margin of safety existed throughout the flight. Tel 2 signal was lost at RO +668 sec. This time encompassed the time of inflight tape recorder playback.

16.2.8.2 Antigua

Continuous coverage was maintained from the Antigua station. Antigua acquired signal at RO +398 sec and maintained good signal strength until RO +941 sec when loss of signal occurred. All RF links ceased at the same time.

The signal strength data from Antigua was completely useless for quantitative analysis but of some use for qualitative analysis. There were rapid excursions in the data throughout the track and in the calibrations varying from 5 to 50 percent of full scale. It appears as though the receivers were improperly tuned, their crystals being out of specification with no allowance made in the intermediate frequency tuning. Also, since all calibration steps showed an equal noise level of approximately 5 percent, there must have been a recorder problem. Real-time data sent to MSFC do not show this noise.

Either the recorder needed re-alignment or the inputs were over-driven. It can be determined, however, that signal strengths are excellent and pattern perturbances are small.

Data taken at Bermuda during the common period of tracking was good, therefore, the noise on the data was assumed to be a ground station problem peculiar to Antigua.

16.2.8.3 Bermuda

Redundant coverage was attained by the Bermuda station. Bermuda acquired signal at RO +239 sec and lost signal at RO +828 sec.

Two charts were obtained from Bermuda. This data was lacking in proper identification. It was not stated whether these two charts were from two different antennas, two different sets of receivers, or just duplicate plots from the same receivers. One of the plots was virtually useless since the gear train locked before S-IVB engine cutoff.

Signal strengths were a nominal 20 μv for the mission with the exceptions of horizon interference and stringent vehicle maneuver periods. During this period, variations between 1 μv and 10 μv were noted. Either right hand circular or left hand circular polarization signals were above threshold at all times, though either may have dropped out for brief periods depending on the look angles from the stage to the ground station.

Signal strength margins were good for the entire mission. The variations due to the stage antenna patterns were as anticipated. Stage orientation angles for the flight are being reduced to provide an antenna pattern comparison between the pattern obtained during the roll maneuver and equivalent scale model patterns. This is being done to determine the integrity of the pattern range used.

16.2.9 Electromagnetic Compatibility

Analysis of telemetry data from the S-IVB-202 flight did not disclose any electromagnetic compatibility problems. Statham pressure transducer amplifiers which were found to be RF susceptible during checkout at Sacramento Test Center (STC) did not give an indication of RF susceptibility during countdown and flight. This is probably due to the low RF field intensity in the S-IVB interstage when the control service module is in place.

PAM links A1 and A2 were very noisy from the Antigua station. Overlapping Tel 2 data did not indicate similar problems. The problem was not resolvable by reduction techniques.

It appears the Antigua ground station inadvertently introduced noise by some electronic means. Similar problems have been encountered at STC which was attributed to receiver and tape recorder.

TABLE 16-1
INSTRUMENTATION SYSTEM PERFORMANCE SUMMARY*

PARAMETER	NUMBER ASSIGNED (IP&CL)	NOT ACTIVE FOR FLIGHT	TELEMETRY BY S-IB STAGE	ASSIGNED FOR FLIGHT	DELETED PRIOR TO LAUNCH	ACTIVE FOR LAUNCH	FAILED	PARTIAL SUCCESS
(A) Acceleration	0	-	-	-	-	-	-	-
(B) Accoustic	6	0	0	6	0	6	0	0
(C) Temperature	163	0	2	161	3	158	0	4
(D) Pressure	79	0	4	75	0	75	0	0
(E) Vibration	36	0	0	38	6	32	0	2
(F) Flow	4	0	0	4	0	4	0	0
(G) Position	8	0	0	8	0	8	0	0
(K) Event	78	19	0	59	0	59	0	0
(L) Liquid Level	6	0	0	6	1	5	0	0
(M) Volt/Current/Freq	44	2	0	42	0	42	0	1
(N) Miscellaneous	32	0	0	32	0	32	0	0
(S) Strain	12	0	0	12	0	12	0	1
(T) Speed	2	0	0	2	0	2	0	0
TOTAL	472	21	6	445	10	435	0	8

* This table summarizes instrumentation system performance from a design requirement point of view. Performance from a data usability viewpoint is summarized at the beginning of section 16.

TABLE 16-2 (Sheet 1 of 2)
INSTRUMENTATION SYSTEM MEASUREMENT STATUS

Measurements Used For Checkout

K0141-411	Event - R/S 1, Pulse Sensor
K0142-411	Event - R/S 2, Pulse Sensor
K0143-404	Event - U/R 1, Ign P/S 1
K0144-404	Event - U/R 1, Ign P/S 2
K0145-404	Event - U/R 2, Ign P/S 1
K0146-404	Event - U/R 2, Ign P/S 2
K0147-404	Event - U/R 3, Ign P/S 1
K0148-404	Event - U/R 3, Ign P/S 2
K0149-404	Event - U/R Jettison 1, P/S
K0150-404	Event - U/R Jettison 2, P/S
K0151-411	Event - PU Oven ON
K0160-414	Event - APS 1, He Reg Hi Press Sw, CL
K0161-414	Event - APS 1, He Reg Low Press Sw, CL
K0162-415	Event - APS 2, He Reg Hi Press Sw, CL
K0163-415	Event - APS 2, He Reg Low Press Sw, CL
K0168-404	Event - Sw Sel Regstr Test
K0169-404	Event - EBW P/S OFF
M0060-411	Volt - PU Valve Contr
M0061-411	Volt - PU Valve Posit, Feedback

Measurements Not Used

K0095-401	Event - Thr Chamb LH2 Inj Temp, OK
K0152-404	Event - Rate Gyro Whl Spd, OK

Measurements Monitored by S-IB Stage

C0251-419	Temp - Ht Flux, Aft Intrstg, Loc 1
C0252-419	Temp - Ht Flux, Aft Intrstg, Loc 2
D0153-423	Press - R/R Chambr, Posit IV/I
D0154-421	Press - R/R Chambr, Posit II/III
D0155-420	Press - R/R Chambr, Posit I/II
D0156-422	Press - R/R Chambr, Posit III/IV

TABLE 16-2 (Sheet 2 of 2)
INSTRUMENTATION SYSTEM MEASUREMENT STATUS

Measurements Deleted Prior to Countdown

C0072-408	Temp - LH2 Tank Wall, Int, Loc 4
E0001-404	Vib - Natural Bend, Aft, Yaw
E0002-404	Vib - Natural Bend, Aft, Pitch
E0003-411	Vib - Natural Bend, Fwd, Pitch
E0004-411	Vib - Natural Bend, Fwd, Yaw
E0181-404	Vib - Natural Bend, Aft, Long
E0182-411	Vib - Natural Bend, Fwd, Long
L0005-406	Level - LOX Tank, Posit 2

Measurements Defective Prior to Automatic Sequence

C0144-401	Temp - LH2 Pump Disch Line Wall
C0145-401	Temp - LOX Pump Disch Line Wall

Measurements with Subnormal Performance (Partial sucess)

C0077-409	Temp - LH2 Tank, Ext, Loc 3
C0078-409	Temp - LH2 Tank, Ext, Loc 4
C0200-401	Temp - LH2 Injection
C0385-401	Temp - Eng T/C Exit Skin, Fin 2-3
E0083-401	Vib - LH2 Turbo Pump (LF), Lat
E0084-401	Vib - LH2 Turbo Pump, Lat
M0024-411	Volt - 5 volt Excit Mod, Fwd

Aberrant Measurement (Trend)

D0059-401	Press - PU Valve Inlet
S0016-426	Strain - Fwd Skirt, Comp, Axial, Loc 1

Measurement Failures

None (Although measurements S0016 and C0134 provide no useful data, their performance was satisfactory from an instrumentation design viewpoint.)

TABLE 16-3 (Sheet 1 of 3)
INSTRUMENTATION SYSTEM MEASUREMENT DETAILS

Measurements Deleted Prior to Flight		
E0001-404	Vib - Natural Bend, Aft, Yaw	These measurements were deleted from the active flight list prior to launch because of an inherent problem in the transducer system. Measurement E0002 was observed utilizing excessive current that was attributed to an electrical short circuit. It was determined that the malfunction was not a random problem but a design defect. Therefore, in order to preclude the failure in the other similar transducer systems, all similar measurements were disconnected. The short circuit was caused by the congested wiring within the transducer amplifier section when an insulated conductor became inadvertently short circuited through its insulation. A redesign of the transducer system is presently in process to remedy the present undesirable condition.
E0002-404	Vib - Natural Bend, Aft, Pitch	
E0003-411	Vib - Natural Bend, Fwd, Pitch	
E0004-411	Vib - Natural Bend, Fwd, Yaw	
E0181-404	Vib - Natural Bend, Aft, Long	
E0182-411	Vib - Natural Bend, Fwd, Long	
L0005-406	Level - LOX Tank, Posit 2	The measurement was deleted from the flight active list after the CDDT because it indicated "wet" when the sensor was not immersed in LOX. The sensor or its associated wiring internal to the LOX tank short circuited causing the control unit to sense a "wet" condition. Since the problem was internal to the tank, no action was taken to remedy the malfunction.
C0072-408	Temp - LH2 Tank Wall, Int, Loc 4	The measurement failed prior to the acceptance firing and was to be replaced if the tank was subsequently entered. Since the tank was not opened the measurement was deleted from the flight active test. The temperature sensor malfunctioned in the open circuit mode. Since the problem was inside the LH2 tank, no action was taken to remedy the malfunction
Partial Successes		
C0077-409	Temp - LH2 Tank, Ext, Loc 3	These measurements failed at RO +610 sec. C0078 failed approximately 1/2 sec later than C0077. Both, however
C0078-409	Temp - LH2 Tank, Ext, Loc 4	

TABLE 16-3 (Sheet 2 of 3)
INSTRUMENTATION SYSTEM MEASUREMENT DETAILS

Partial Successes (Cont.)		indicated a short circuit condition. These malfunctions occurred at the time when the spacecraft engine ignited. It appeared that flame impingement could have caused short circuit, however, C0077 and C0078 were on different cables and C0078 was 123 in. farther aft and 60 deg apart on the LH2 tank. Measurement C0076 was in axial alignment and 123 in. aft of C0077, also on the same cable, however, no abnormal response was observed.
C0200-401	Temp - LH2 Injection	The measurement indicated satisfactory performance at the time of interest (J-2 engine start), however, the transducer failed in the open circuit mode at RO +486.5 sec. A vibration environment might be responsible for the malfunction. The transducer was supplied by Rocketdyne with the J-2 engine.
C0385-401	Temp - Eng T/C Exit Skin, Fin 2-3	The measurement provided satisfactory information at the time of interest (j-2 engine start), however, the transducer failed shortly thereafter in the open-circuit condition at RO +196 sec. The malfunction might have been caused by vibration due to engine firing. This transducer was supplied by Rocketdyne with the J-2 engine.
E0083-401 E0084-401	Vib - LH2 Turbo Pump (LF), Lat Vib - LH2 Turbo Pump, Lat	These measurements satisfied engineering analysis criterion; however, the response was not completely satisfactory. It appears the response was erratic during the midpoint of S-IVB firing. The erratic signal was not attributed to turbopump characteristics but was possibly caused by low frequency components introduced by transducer system low frequency bias variations. The overall high amplitude of the vibration root-mean-square level could also be attributed to these low frequency components.
M0024-411	Volt - 5 Volt Excit Mod, Fwd	The measurement failed to indicate valid data after RO +610 sec. A discontinuity of the voltage sensing system caused the loss of data. The loss of the 5 volt signal was not detrimental to the 5-volt excitation power system.

TABLE 16-3 (Sheet 3 of 3)
INSTRUMENTATION SYSTEM MEASUREMENT DETAILS

Measurements Defective Prior to Automatic Sequence		
C0144-401 C0145-401	Temp - LH2 Pump Disch Line, Wall Temp - LOX Pump Disch Line, Wall	These measurements failed to present valid data. They were expected to indicate on-scale data sometime during the flight test, however, they were constantly off-scale-high. It is suspected that these sensors, which were the fiber-glass type, debonded from the applied surface, consequently, indicating a temperature close to ambient that was far beyond the upper range of the measured range. On subsequent stages a ceramic type sensor with a superior bonding technique will be used to remedy the present unsatisfactory condition.
Trend Data Measurement		
D0058-401	Press - PU Valve Inlet	The measurement was known to exhibit trend information prior to launch. The RACS calibration on both high and low levels was 6 percent low. This indication was verified by comparing the data with known pressure times. The data was, however, usable for engineering evaluation. The calibration shift was probably caused by a bias shift of the transducer amplifier. The transducer system was supplied by Rocketdyne with the J-2 engine.
S0016-426	Strain - Fwd Skirt, Comp, Axial, Loc 1	The measurement was considered a failure by the requesting design section because the strain gage responded to temperature changes as well as strain. The response to temperature was observed on a previous stage and was attributed to strain gage location and mounting configuration. This condition will be rectified on subsequent stages.

TABLE 16-4
RF AND ANTENNA SYSTEM PERFORMANCE

RF SYSTEM PERFORMANCE

S-IVB Link	Frequency (MHz)	Output Power (Watts)
CF1	258.5	30.4
CF2	246.3	26.6
CF3	253.8	36.4
CP1	232.9	31.2
CS1	226.2	32.8

ANTENNA SYSTEM PERFORMANCE

Antenna System	VSWR	Insertion Loss	VSWR During Blackout
1	1.8:1	4.9 db	4.63:1
2	1.2:1	6.4 db	1.47:1
3	1.3:1	6.4 db	2.40:1
4	1.3:1	6.1 db	1.95:1

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17. ELECTRICAL SYSTEM PERFORMANCE

The electrical control system and the electrical power system performed satisfactorily during powered flight. The only difference between the S-IVB-202 and S-IVB-201 electrical systems was the installation on S-IVB-202 of an MSFC Saturn Secure Range Safety Command System, Model DSV-4B-2-30.

17.1 Electrical Control System

All electrical control system events which occurred as a result of a switch selector command performed satisfactorily. The sequence of events is given in section 4 and non-programmed events are presented below.

17.1.1 J-2 Engine Control System

All event measurements verified that the engine control system responded properly to Engine Start and Cutoff Commands. Engine Start Command was received at the J-2 engine at range zero (RO) +145.624 sec. Engine cutoff was initiated at RO +588.473 sec. Total engine burntime was 442.849 sec. All events occurred in their proper sequential order and within the allowable time spans. All event measurements performed satisfactorily.

17.1.2 Vent Valves

The LOX and LH2 vent valve open commands were not given during S-IVB powered flight. The LOX and LH2 vent valves were closed completely during J-2 engine burn. Vent valve performance was satisfactory throughout flight.

17.1.3 Fill and Drain Valves

Prior to liftoff, the fill and drain valves were closed through the umbilical and remained closed throughout the mission as expected.

17.1.4 Control Pressure Switches

The LOX and LH2 prepressurization flight switches operated within specified pressure limits. Switch performance was satisfactory.

The pump control regulator backup pressure switch was not actuated throughout flight since the actuation pressure of 130 psia was not reached. Switch performance was nominal.

The LOX chilldown purge switch performed satisfactorily.

The LOX tank regulator backup pressure switch was not actuated during flight since actuation pressure was never attained. Switch performance was nominal.

17.1.5 Auxiliary Propulsion System

Event and pressure measurements indicated that the APS engine feed valves responded to all commands, verifying that the electrical control system performed within prescribed limitations.

17.1.6 Recirculation Shutoff Valves

Prior to J-2 engine start the recirculation shutoff valves (SOV) were commanded closed by the switch selector and the valves left the open position, thus verifying the electrical system integrity. However, measurement K0136, Fuel SOV Chill System Closed, failed to indicate that the fuel recirculation shutoff valve had closed. A review of measurement F0005, Flowrate Fuel Circulation Pump, indicated a flowrate of 68 gpm throughout engine burn. This data verified that the valve had failed to close completely.

17.2 Electrical Power System

17.2.1 Flight Batteries

The four flight batteries, forward batteries No. 1 and No. 2, and aft batteries No. 1 and No. 2 performed within the expected limits. Battery load and temperature profiles are presented in figures 17-1 and 17-2.

17.2.2 Chilldown Inverters

The chilldown inverters performed satisfactorily. Inverter temperatures were within expected limits. The LOX inverter temperature at chilldown activation was 470 deg R and increased linearily until it reached 479 deg R at which time the inverter was sequenced off. The LH2 inverter temperature was 474 deg R at inverter activation and increased to 481 deg R at inverter shutdown.

Measurement No.	Measurement Title	Acceptable Range	Actual
M0026	Volt A-B Fuel Chilldown Inv	50-60 vac	54 v
M0027	Volt A-B LOX Chilldown Inv	50-60 vac	54 v
M0029	Freq LOX Chilldown Inv	390-410 cps	401 cps
M0040	Volt A-C LOX Chilldown Inv	50-60 vac	54 v
M0041	Volt A-C Fuel Chilldown Inv	50-60 vac	54 v
M0044	Volt A-B LOX Chilldown Inv	50-60 vac	54 v
M0045	Volt A-C LOX Chilldown Inv	50-60 vac	54 v
M0046	Volt A-B Fuel Chilldown Inv	50-60 vac	54 v
M0047	Volt A-C Fuel Chilldown Inv	50-60 vac	54 v
M0028	Freq Fuel Chilldown Inv	390-410 cps	400 cps

17.2.3 5-Volt Excitation Modules

The 5-volt excitation modules performed satisfactorily throughout the flight. At RO +612 sec measurement M0024 apparently failed due to the effects of SPS engine plume impingement. The forward 5-volt excitation module reference voltage is not believed to have been changed by this disturbance. The following table presents the performance of the 5-volt excitation modules during flight.

Measurement No.	Measurement Title	Acceptable Range	Actual
M0024	Volt 5-Volt Excit. Mod. Fwd	4.95 to 5.05 v	4.98 v
M0025	Volt 5-Volt Excit. Mod. Aft	4.95 to 5.05 v	4.98 v
M0042	Freq 5-Volt Excit. Mod. Aft	1,800-2,200 cps	2,000 cps
M0043	Freq 5-Volt Excit. Mod. Fwd	1,800-2,200 cps	2,007 cps

17.2.4 Static Inverter-Converter

Static inverter-converter performance was nominal throughout the flight as indicated by the following table.

Measurement No.	Measurement Title	Acceptable Range	Actual
M0001	Volt-Static Inv. - Conv.	110-120 vac	115.6 vac
M0004	Volt-Static Inv. - Conv.	4.5-5.5 vdc	5.25 vdc
M0012	Freq. Static Inv. - Conv.	390-410 cps	402.6 cps
M0023	Volt-Static Inv. - Conv.	20-22 vdc	21.76 vdc

The temperature at inverter activation was 530 deg R and remained constant during powered flight.

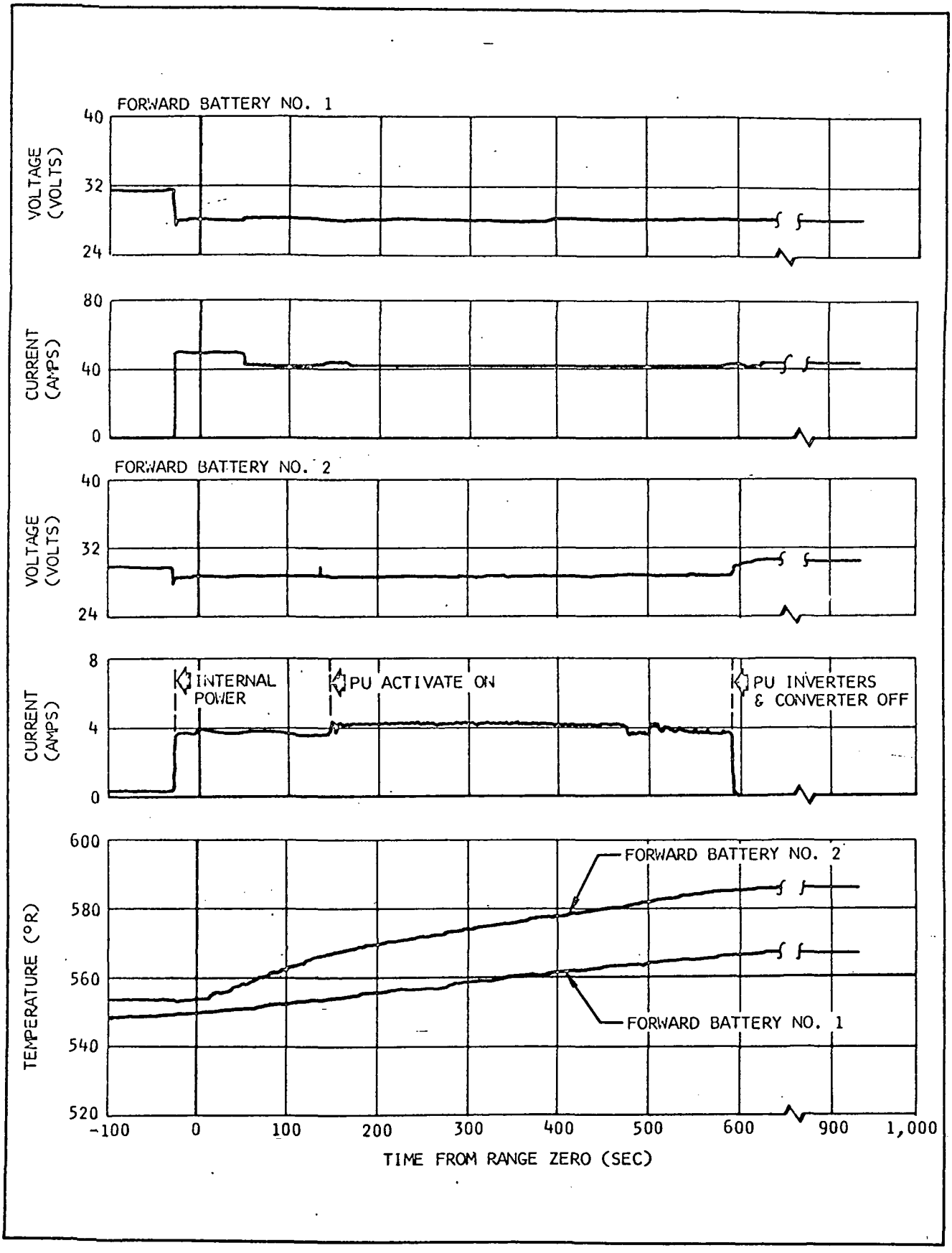

Figure 17-1. Forward Battery No. 1 and No. 2 Performance

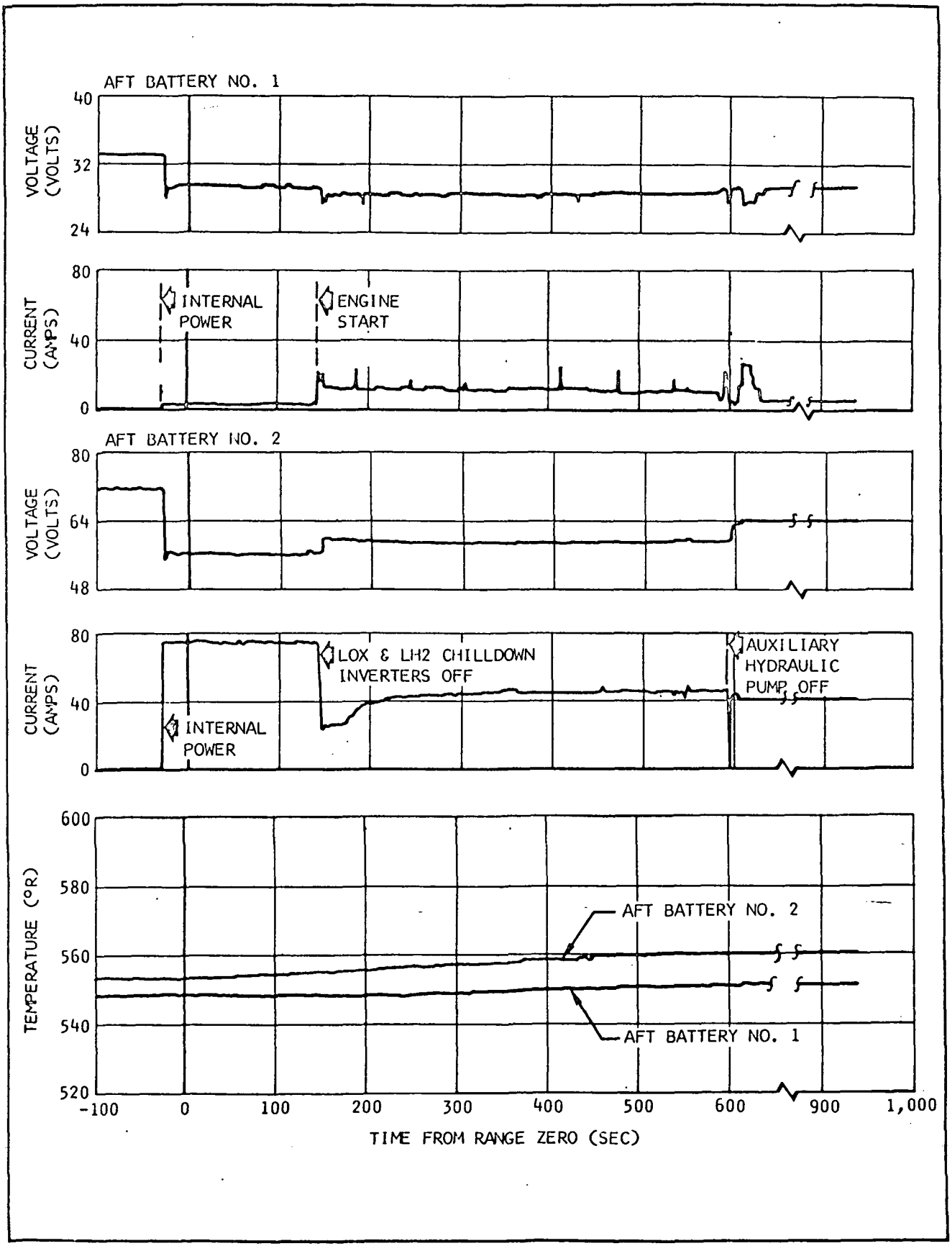

Figure 17-2. Aft Battery No. 1 and No. 2 Performance

24 October 1966

18. Range Safety System Performance

The range safety system was not required for propellant dispersion during the flight. All indications were that the system was operating properly and would have properly executed its function, had it been called upon to do so.

18.1 Controllers

The controllers are designed to distribute command signals for engine cutoff, exploding bridgewire (EBW) charge and fire, and to distribute power to the range safety receivers. No abnormal conditions were evident.

18.2 Firing Units Monitors

The EBW firing units were not charged throughout the flight.

18.3 Receivers Signal Strength

The signal strength was well above threshold for the entire duration of the powered flight with the exception of a 1.8 sec blackout starting at retrorocket ignition. This condition was expected to exist and is not considered to be an anomaly. The signal strength remained saturated until the Safe Command was sent at RO +597.5 sec. The range safety system satisfactorily responded to the Safe Command.

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19. FLIGHT CONTROL

The main engine control system provided satisfactory pitch and yaw control throughout the S-IVB powered flight. The transients experienced during separation, guidance initiation, artificial tau mode, introduction of chi tilde ($\tilde{\chi}$) guidance mode, and S-IVB engine cutoff, were well within the capabilities of the control system. The most significant control system transient occurred following guidance initiation. The maximum pitch and yaw attitude errors and corresponding pitch and yaw engine deflections were as follows:

ITEM	PITCH	YAW
Attitude error	-1.6 deg (nose down)	-1.15 deg (nose left)
Engine deflection	+0.80 deg	-0.62 deg

The engine control system responded correctly to command currents from the actuator servo valve amplifiers during S-IVB flight.

The auxiliary attitude control system (AACS) provided satisfactory roll stabilization during S-IVB powered flight and satisfactory pitch, yaw and roll stabilization following J-2 engine cutoff. The stage roll disturbances during S-IB/S-IVB separation were in the same direction as in AS-201 and AS-203 flights but of much larger magnitude. Approximately three times as many engine firings were required on AS-202 as on AS-201 to provide roll stabilization after separation. Approximately twice as many engine firings were required on AS-202 as on AS-201 to provide roll stabilization following initiation of the iterative guidance mode (each of these disturbances was relatively small on AS-203).

Steady-state roll torque during powered flight was approximately 20 ft-lbf (counter-clockwise looking forward); this is slightly higher than the 16 ft-lbf seen on AS-201 (clockwise looking forward) and much larger than the 6 ft-lbf seen on AS-203 (counter-clockwise looking forward). It was, however, much less than the 100 ft-lbf value upon which the APS propellant allocations were based.

Initial slosh heights derived from LH2 tank probe data were considerably less than observed on AS-201 and approximately the same as those observed on AS-203. LOX slosh heights observed by the PU probe were smaller in magnitude than those which occurred on AS-201. LH2 slosh frequency was predominately first mode and was of sufficient magnitude to cause oscillations in the pitch rate gyro and pitch actuator differential pressure. LOX frequencies fell between predicted first and second modes, apparently as a result of LOX second mode being driven at LH2 first mode frequencies. LOX sloshing, however, had no noticeable effect on the control system.

The performance of the flight control system during sub-orbital coast phase of flight is discussed in section 25.

19.1 Main Engine Control System

The main engine control system performed satisfactorily throughout S-IVB powered flight. The major areas of interest during S-IVB powered flight are S-IB/S-IVB separation, initiation of the iterative guidance mode, artificial tau mode, initiation of the chi tilde ($\tilde{\chi}$) guidance mode, and S-IVB engine cutoff. The transients resulting from each of these vehicle disturbances during flight were well within the capabilities of the main engine control system. The magnitude of these transients were comparable to those observed on AS-201 and AS-203, although the settling times following separation and guidance initiation were longer, which indicates a reduction in the system damping. Attitude errors, attitude rates, and actuator positions during powered flight are shown in figures 19-1, 19-2, and 19-3, respectively. Critical control system parameters observed during the transient portions of flight are summarized in table 19-1.

S-IB/S-IVB separation occurred at R0 +144.27 sec; guidance initiation occurred at R0 +172.4 sec. The LET jettison occurred just prior to guidance initiation (R0 +169 sec) but had very little effect on attitude errors and attitude rates. An approximate closed loop simulation of the attitude error and rate transients following separation and guidance initiation was obtained using the following conditions at separation.

Pitch attitude error	0	deg
Yaw attitude error	+0.42	deg

Angular pitch rate	+0.05 deg/sec
Angular yaw rate	+0.14 deg/sec
Pitch angle of attack	-0.8 deg
Yaw angle of attack	0 deg
Pitch thrust vector misalignment	-0.25 deg
Yaw thrust vector misalignment	-0.53 deg

A comparison of the control parameters from the simulations and those obtained from telemetry data is shown in figures 19-4 and 19-5. This comparison indicates that the system damping during flight was less than that included in the simulation. This reduction in damping could result from rigid body corss-axis coupling, J-2 engine thrust vector control system cross coupling, or a reduction in the rate feedback gain. Further simulations are being run to determine which of these effects or combination of these effects give the best match of flight data. The values of thrust vector misalignments shown above do not include center of gravity (CG) offset but may include the effects of thrust vector offset, thrust structure compliance, or an internal electrical bias signal in the control system. These values of thrust vector misalignment compare favorably with values (-0.268 deg in pitch and -0.515 deg in yaw) determined from a trajectory simulation analysis. The above engine misalignments are within the three-sigma alignment tolerances. The response of the actuators to the servo valve command current was simulated for the period during the guidance initiation transient and the results are presented in figure 19-6. The close agreement between the data from the flight and that from the simulation indicates that the actuators were responding correctly to the command currents.

Steady-state pitch and yaw attitude errors differed slightly from predicted values. A comparison between the preflight predicted steady-state attitude errors and the attitude errors seen in flight are presented for two times of flight in the table below.

ITEM	PITCH ATTITUDE ERROR	YAW ATTITUDE ERROR	TIME FROM RANGE ZERO
Actual	+0.2 (Nose Up) 0	0 -0.35 (Nose Left)	220 490
Preflight Predicted	-0.43 (Nose Down) -0.36 (Nose Down)	-0.63 (Nose Left) -0.87 (Nose Left)	220 490

As may be seen from the table, the changes in steady-state attitude errors during flight agrees closely with those predicted. The difference in the magnitudes of the predicted and actual steady-state pitch attitude errors are attributed primarily to thrust vector misalignment. The difference in the magnitudes of the predicted and actual steady-state yaw attitude errors are attributed to a combination of thrust vector misalignment and a bias in the command current to the servo-valve. The presence of the command current bias is indicated by the discrepancy between the telemetered yaw actuator positions and those computed by the steady-state control equation as seen in figure 19-3. This bias was observed in prelaunch checkout tests. The close agreement between the telemetered pitch actuator positions and those computed from the steady-state control equation indicate that there was no significant bias in the pitch command current. The predicted values included the effects of CG offset and assumed zero pitch engine misalignment and a -0.52 deg yaw engine misalignment.

The artificial tau mode was initiated at RO +499.1 sec. The large pitch transient excited at this time was probably due to the 28 sec delay between the expected and actual PU valve cutback. The introduction of chi tilde ($\tilde{\chi}$) guidance mode occurred at RO +546.0 sec. The large pitch transient which occurred following this time resulted from variations in the pitch commands. There were no significant yaw transients excited by introduction of either of the above guidance modes.

Figures 19-7 and 19-8 present the results of a simulation of the pitch attitude error and rate transients following the introduction of the artificial tau mode and extending through the transient generated by the introduction of the chi tilde ($\tilde{\chi}$) guidance mode. The close agreement between the simulation results and the flight data indicates that the control system was performing as designed.

19.2 Roll Control During S-IVB Powered Flight

The AACS provided satisfactory vehicle roll control and stabilization during S-IVB powered flight. The orientation and designations of the control engines are shown in figure 19-9.

The vehicle attitude errors and angular rates for the S-IVB powered flight are presented in figures 19-1 and 19-2 and the corresponding AACS firing history is shown in figure 19-10. Roll engines I_{IV} and III_{II} corrected the roll disturbances induced at separation through main engine activation and gimbaling and CG offsets. Roll engines I_{IV} and III_{II} corrected the initial roll disturbances induced at guidance initiation, and roll stabilization was achieved by firing engines I_{II} and III_{IV}, and then engines I_{IV} and III_{II} again. After stabilization, engines I_{IV} and III_{II} fired intermittently throughout powered flight to counteract the steady-state roll torque.

Due to AACS spatial amplifier tolerances, the roll engines did not always fire as a pair during S-IVB powered flight. The yaw moments introduced by the non-symmetrical APS firings did not have a significant effect on the main engine control system.

The total APS impulse usage during S-IVB powered flight was 548.5 lbf-sec for module 1 and 724.3 lbf-sec for module 2. The predicted nominal and three-sigma values of impulse usage per module during powered flight are 315 and 1,305 lbf-sec, respectively. The impulse used was within the predicted three-sigma value. A time history of the impulse usage required for roll control during S-IVB powered flight is shown in figure 19-11.

Vehicle roll transients resulting from separation and main engine gimbaling were damped out about 24 sec after separation. During this interval the impulse usage was 202.3 and 172.0 lbf-sec for engines I_{IV} and III_{II}, respectively. The three-sigma allowance for this disturbance was 450 lbf/module.

APS engines III_{IV}, I_{II}, III_{II} and I_{IV} fired intermittently from approximately R0 +175.5 sec until R0 +193 sec to counteract the roll disturbances induced by LET jettison and guidance initiation. The resulting roll transient was damped out by the AACS in approximately 18 sec. During this

interval the impulse usage was 52.5 and 52.8 lbf-sec from engines I_{IV} and III_{II}, respectively; then 68.6 and 59.4 lbf-sec from engines I_{II} and III_{IV}, respectively; and finally, engines I_{IV} and III_{II} fired again using impulses of 23.8 lbf-sec and 30.3 lbf-sec to damp out the roll disturbance.

During the interval from R0 +200 sec to J-2 engine cutoff at R0 +588.5 sec all engine firings are attributed to disturbances induced by the J-2 engine swirl moments. The impulse usage was 201.3 lbf-sec for module 1 (engine I_{IV}) and 409.8 lbf-sec for module 2 (engine III_{II}). The interval from R0 +340 sec to R0 +440 sec was used to determine the swirl moment. The impulse usage was 56.3 and 116.0 lbf-sec for engines I_{IV} and III_{II}, respectively. The steady-state roll moment was thus determined to be approximately 20 ft-lbf tending to rotate the vehicle counterclockwise looking forward.

No roll impulse usage is attributed to PU cutback or guidance staging. In this flight, conditions during this interval were such that the swirl moment was reduced due to lowered thrust and was partly counteracted by main engine gimbaling. This is evident by the decrease in engine firing frequency over the time interval concerned.

A summary of impulse usage during powered flight is shown in table 19-2.

19.3 Sloshing

Slosh Frequencies

LOX and LH2 slosh frequencies during S-IVB-202 powered flight were determined from PU fine mass sensor data. Figure 19-12 shows the time history of the LOX and LH2 frequencies and a comparison with theoretically predicted values.

LOX slosh frequencies fell between predicted first and second mode frequencies. This behavior was also observed on AS-203. Three possible reasons serve to explain this effect: (1) LOX coupling with the control system (2) LOX being driven by control system limit cycling; and (3) LOX being driven at LH2 first mode frequencies causing beating between the driving frequency and the second mode LOX frequency. Figure 19-12 shows the theoretical LOX frequency resulting from the

beating phenomena described. This compares favorably with the actual frequencies observed indicating that the third explanation described above is the most probable explanation. Studies involving simulation techniques are continuing to evaluate the other possible explanations.

LH2 slosh frequency data indicated predominently first mode sloshing throughout powered flight. Unlike AS-201 LH2 slosh behavior, where second mode slosh frequency was observed near the end of the powered flight, the LH2 frequency history on AS-202 followed the predicted curve almost exactly throughout the flight. Figure 19-12 shows the frequency history of LH2 during powered flight. As may be seen from this figure, oscillations at the LH2 first mode frequency were observed in the pitch actuator differential pressure data.

The LH2 slosh amplitudes sensed by the PU probe during S-IB and S-IVB powered flights are shown in figure 19-13. Using analytically predicted PU probe hydrodynamic attenuation characteristics, the indicated slosh heights at the probe were corrected to give the actual slosh heights. The maximum slosh height at the PU probe during the S-IVB powered flight was 13.3 in. zero-to-peak and occurred during the S-IB/S-IVB separation transient. Analysis of pitch rate gyro and pitch actuator differential pressure data indicated oscillations occurring at the LH2 sloshing frequency. No such oscillations showed up on the yaw rate gyro or yaw actuator differential pressure data; thus indicating the LH2 sloshing was predominantly in the pitch plane. Maximum slosh height at the tank wall was calculated to be 27.6 in. zero-to-peak. This was less than half of the maximum amplitude observed on the AS-201 vehicle and comparable to that observed on the AS-203 vehicle. Control system performance was not significantly affected by the LH2 sloshing.

The slosh heights sensed at the LOX PU probe during S-IVB powered flight are shown in figure 19-14. The LOX slosh heights seen during the AS-202 flight follow a pattern similar to those seen on AS-201 but are smaller in magnitude. No attempt was made to predict slosh amplitudes at the wall since slosh direction was impossible to ascertain.

Unlike the LH2 PU probe, the LOX probe has no hydrodynamic attenuation characteristics at the LOX frequencies experienced and therefore, no correction of the indicated slosh heights are necessary.

19.4 Body Bending

Pitch and yaw body bending data were not available. The body bending accelerometers were disconnected prior to flight as a result of internal shorts which occurred in several of the accelerometers (section 16). Based on previous Saturn flights, body bending was not expected to have a noticeable effect on the control system.

TABLE 19-1
MAXIMUM VALUES OF CRITICAL PARAMETERS

PARAMETER	SEPARATION	INITIATION OF ITERATIVE GUIDANCE	ARTIFICIAL TAU MODE	INITIATION OF CHI TILDE GUIDANCE	S-IVB ENGINE CUTOFF*
Pitch Attitude Error (deg)	±0.3	-1.6	1.0	-1.0	+2.35
Yaw Attitude Error (deg)	-0.8	-1.15	Negligible	Negligible	+1.0
Roll Attitude Error (deg)	-0.6	-0.40	Negligible	Negligible	+1.0
Pitch Rate (deg/sec)	-0.48	+1.4	1.05	+0.85	+0.16
Yaw Rate (deg/sec)	-0.6	+0.90	Negligible	Negligible	+1.16
Roll Rate (deg/sec)	+0.2	+0.35	Negligible	Negligible	+0.2
Pitch Actuator Position (deg)	+0.19**	+0.80**	+0.3**	-0.3	+0.1***
Yaw Actuator Position (deg)	-0.95**	-0.62**	0**	0.0	-1.49***

* Maximum values during period from Engine Cutoff Command and activation of APS, approximately 5 sec.

** These values do not include steady-state engine deflection required to trim for S-IVB CG offset.

*** These values represent the total actuator deflections from S-IVB engine cutoff to initiation of the S-IVB coast mode.

TABLE 19-2
APS EVENTS SUMMARY

EVENT	MODULE 1		MODULE 2	
	NO. OF PULSES	IMPULSE (lbf-sec)	NO. OF PULSES	IMPULSE (lbf-sec)
Separation and ullage rocket disturbance	25	202.3	23	172.0
LET jettison and guidance initiation	19	144.9	19	142.5
Limit cycle oper until engine cutoff	25	201.3	53	409.8
Total powered roll	69	548.5	95	724.3
Initial convergence following engine cutoff and spacecraft separation	60*	1,098	31*	722
SPS impingement transient		2,210**		5,642**
LOX blowdown		300†		0†
Roll maneuver		0		73.5
Miscellaneous limit cycle		1,037		489
Total coast phase		4,645		6,227

* Not all pulses are minimum pulses; see figure 25-6.

** These values include estimated impulse usage during tape recorder playback.

† Estimated values.

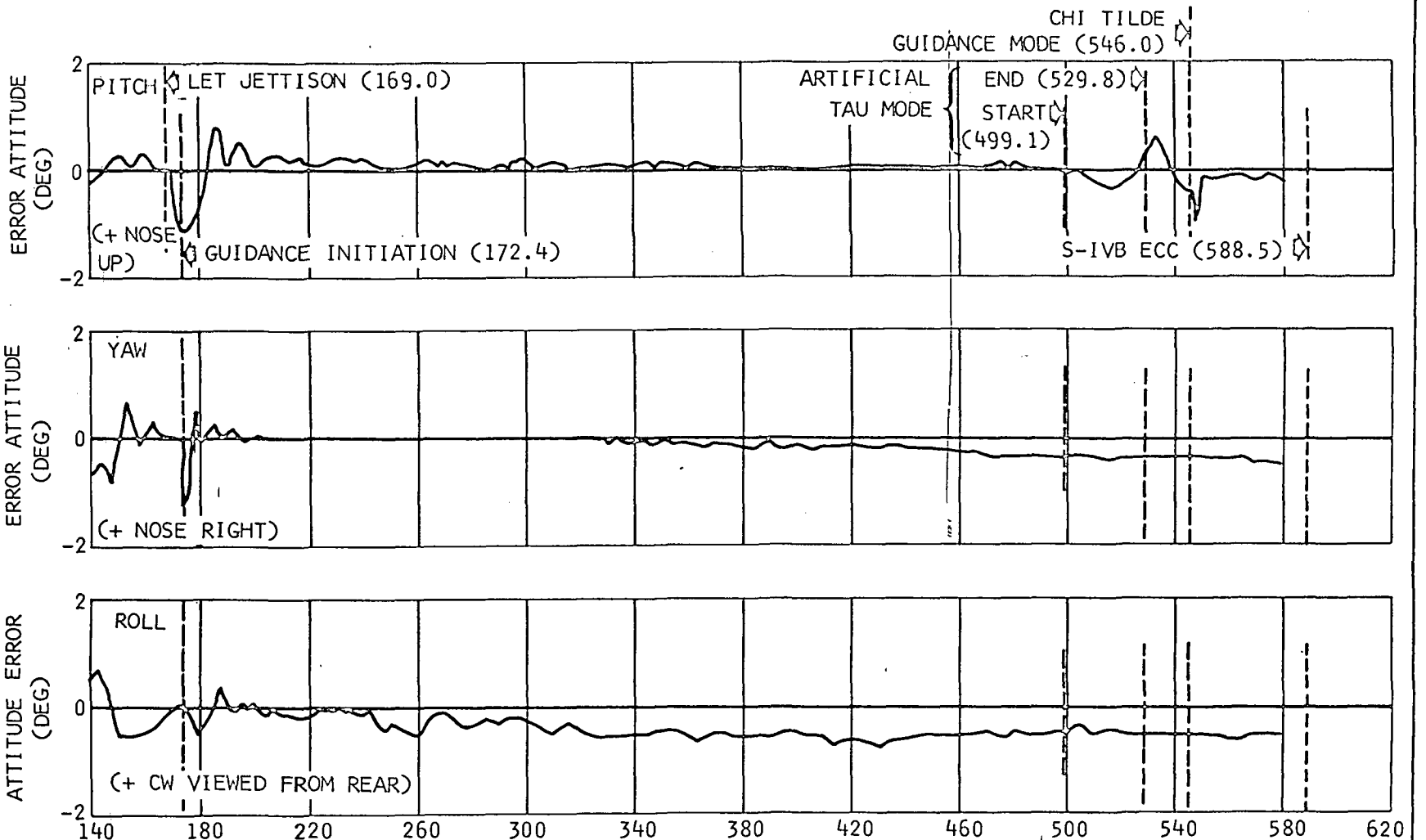

Figure 19-1. S-IVB Attitude Errors Powered Flight

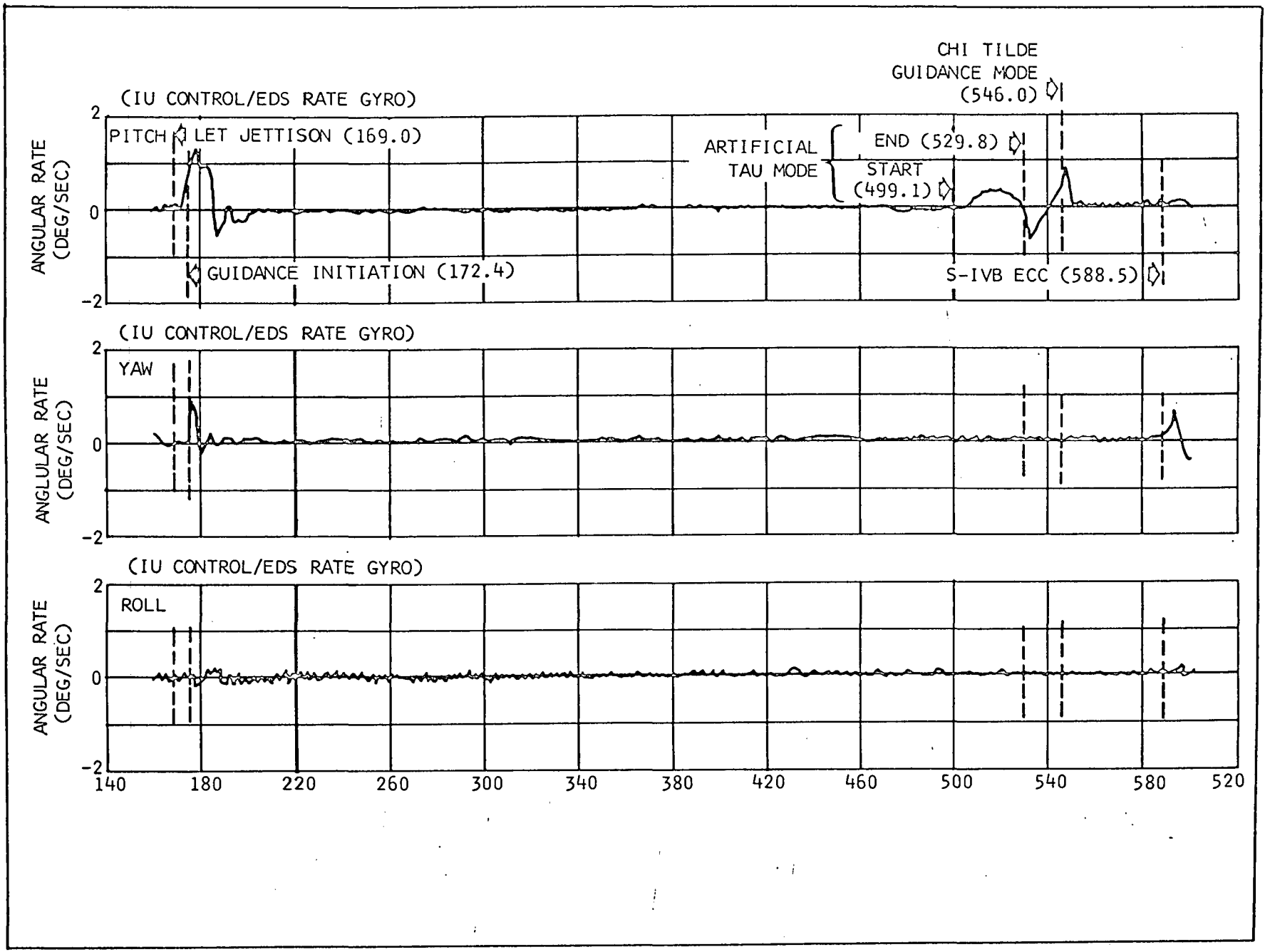

Figure 19-2. Angular Rate Gyros S-IVB Power Flight

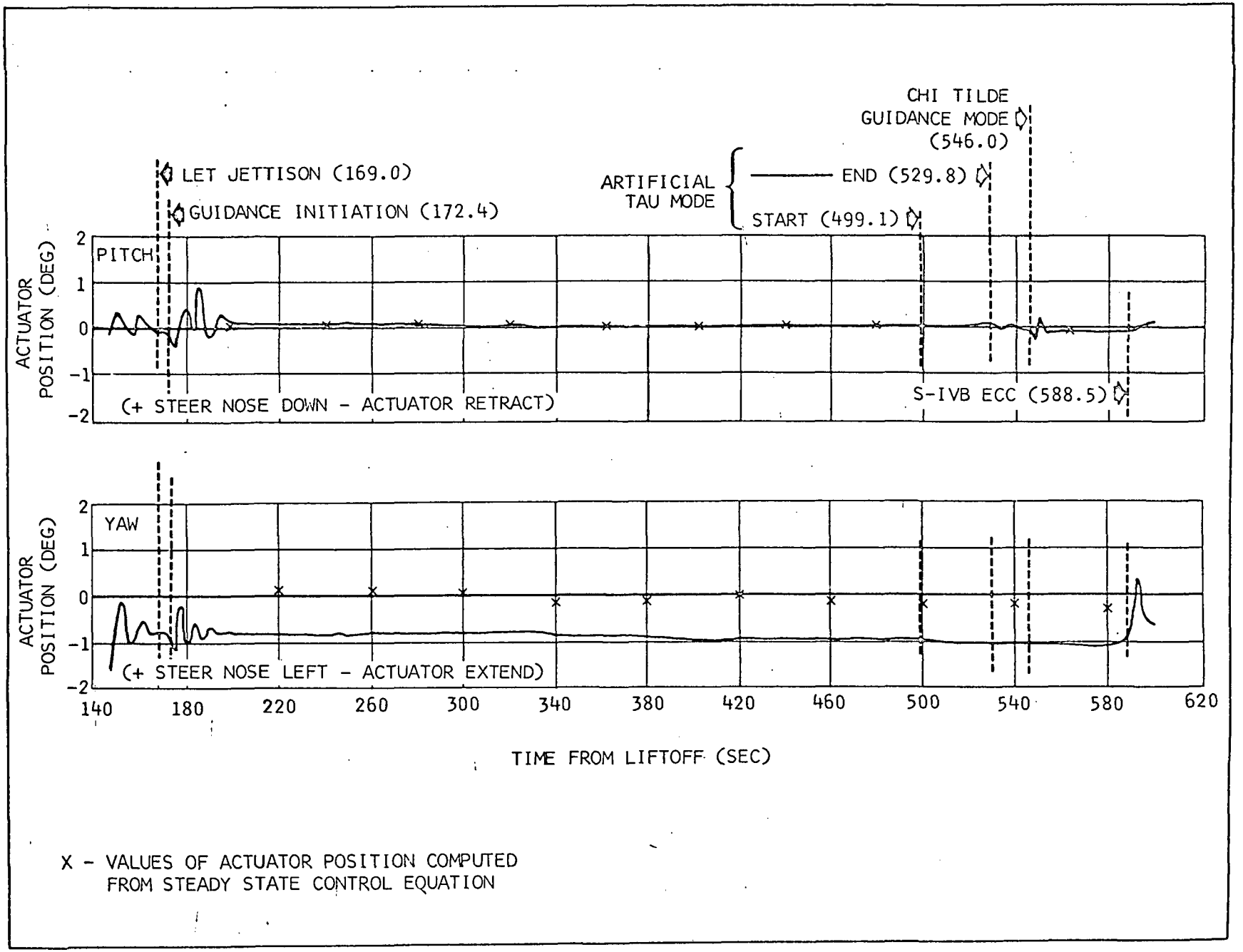

Figure 19-3. Actuator Positions During S-IVB Powered Flight

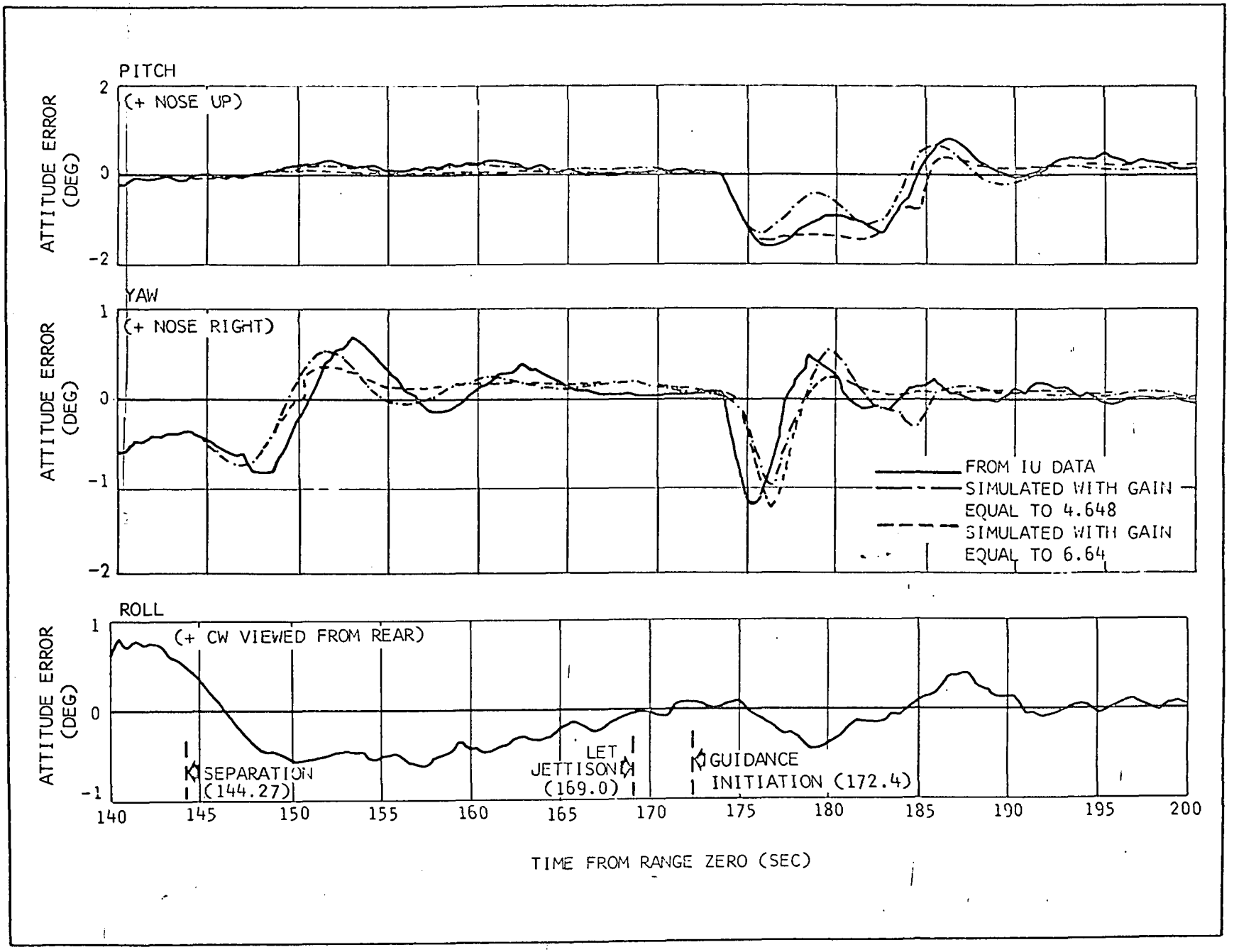

Figure 19-4. S-IVB/202 Attitude Errors at S-IB/S-IVB Separation

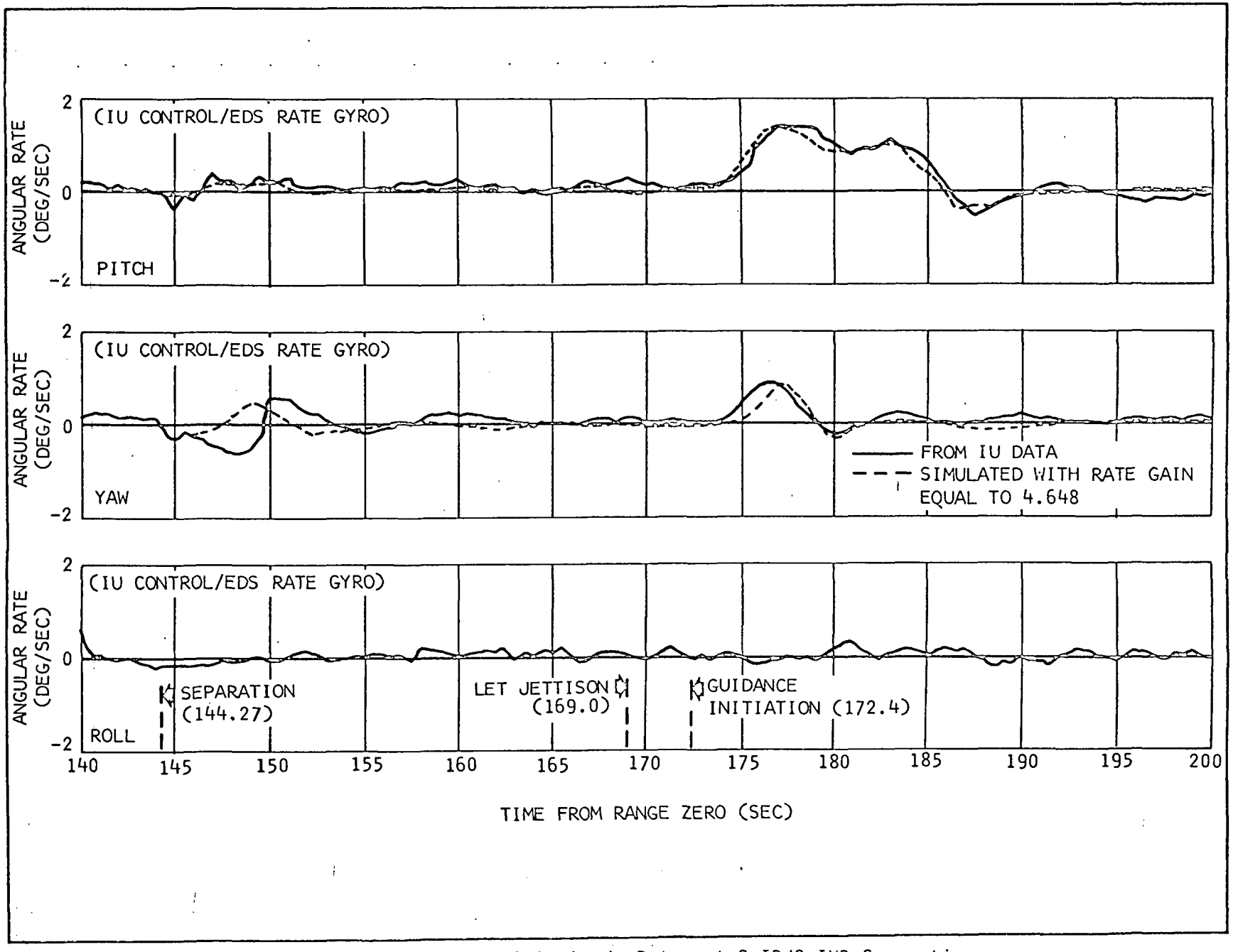

Figure 19-5. S-IVB/202 Attitude Rates at S-IB/S-IVB Separation

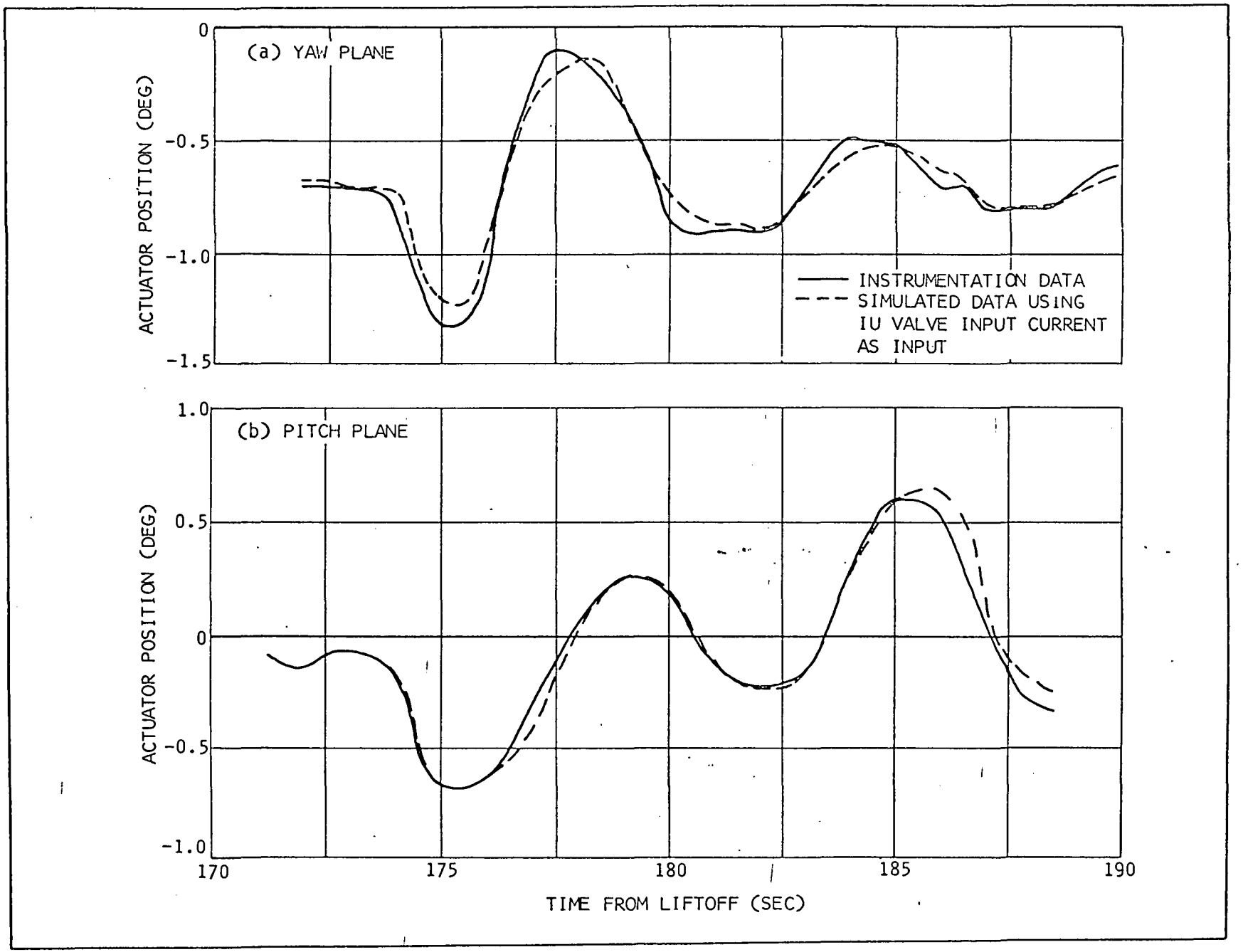

Figure 19-6. Recorded and Simulated Actuator Position During Guidance Initiation

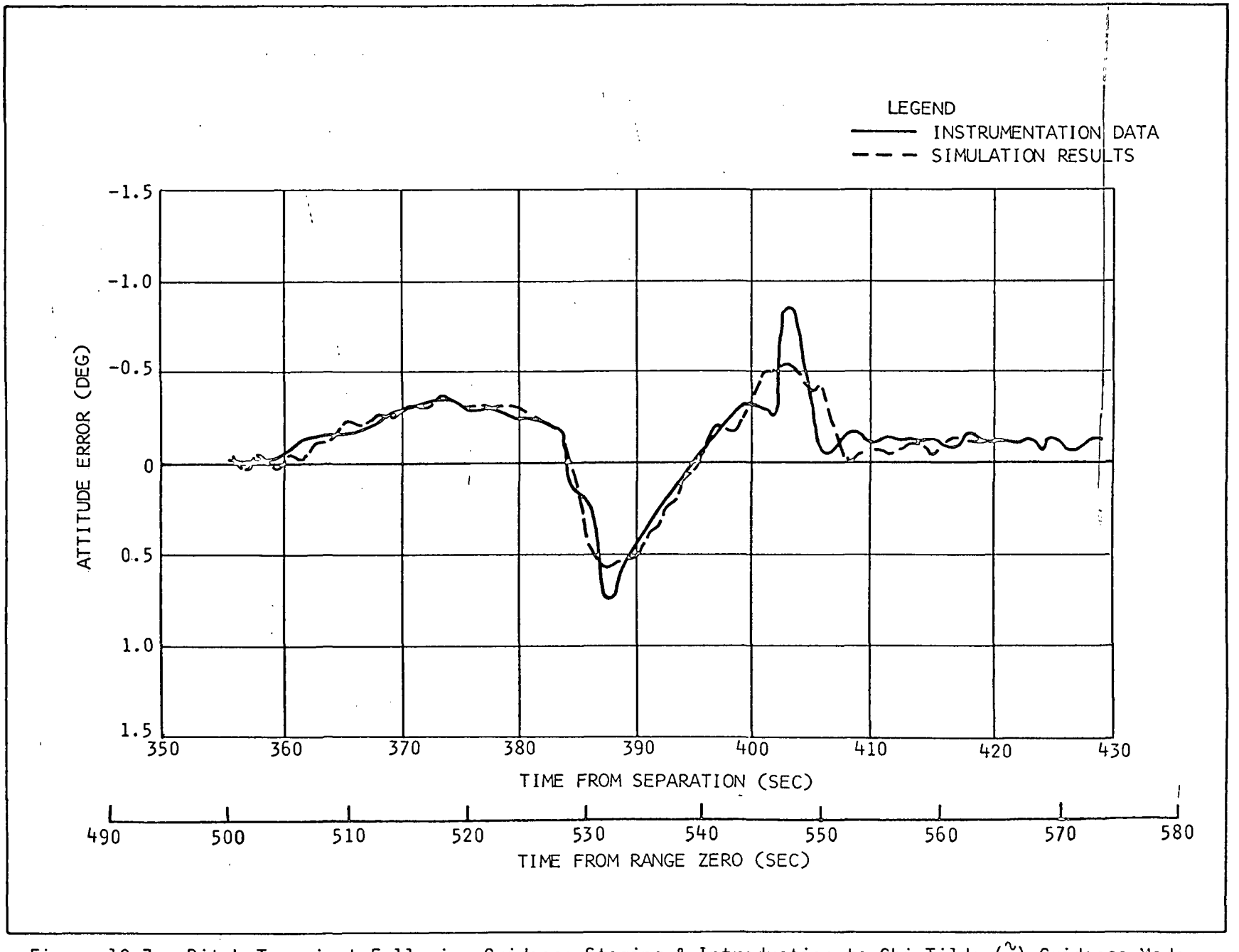

Figure 19-7. Pitch Transient Following Guidance Staging & Introduction to Chi Tilde ($\tilde{\chi}$) Guidance Mode

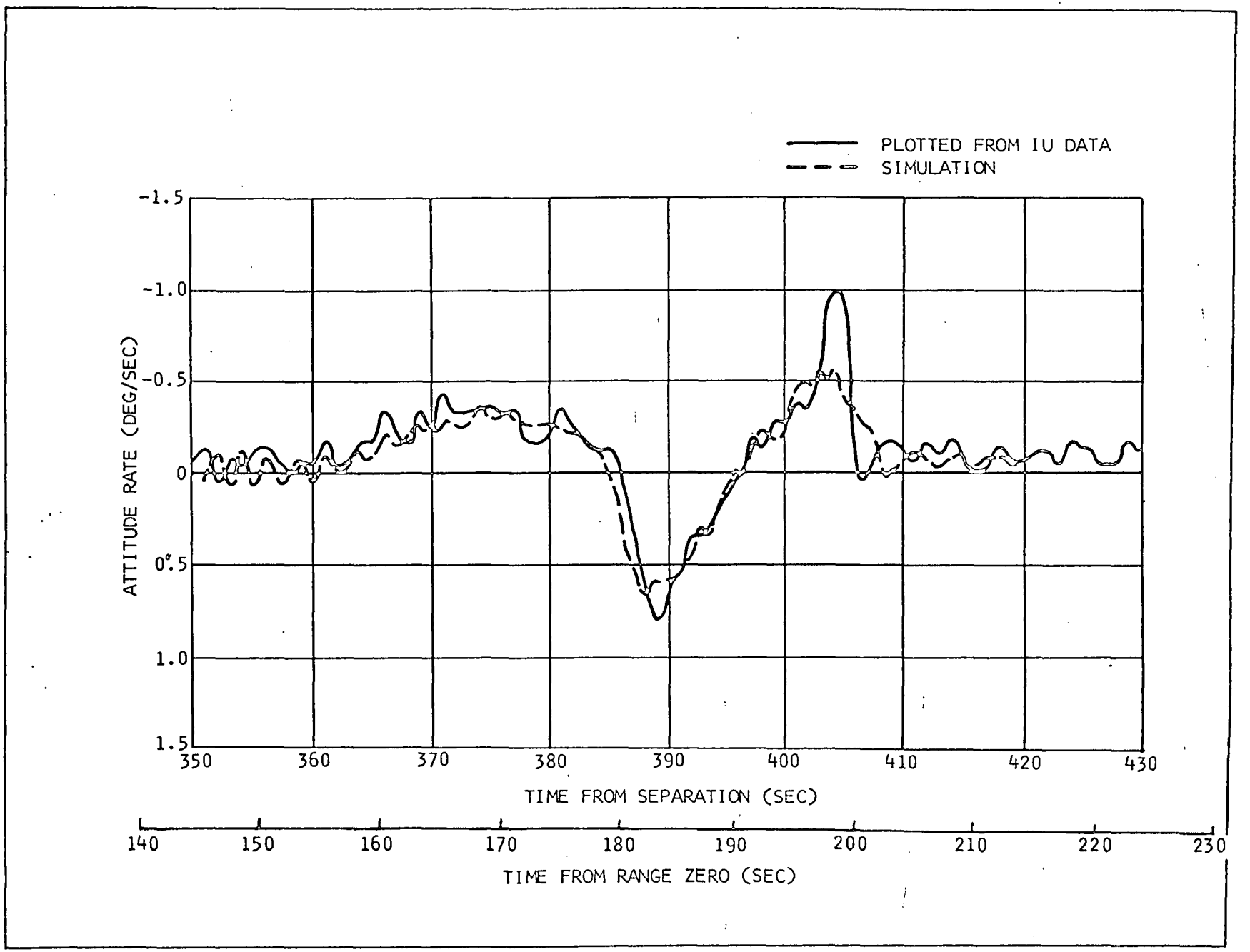

Figure 19-8. Pitch Rate Transient Following Guidance Staging and Introduction of Chi Tilde ($\tilde{\chi}$) Guidance Mode

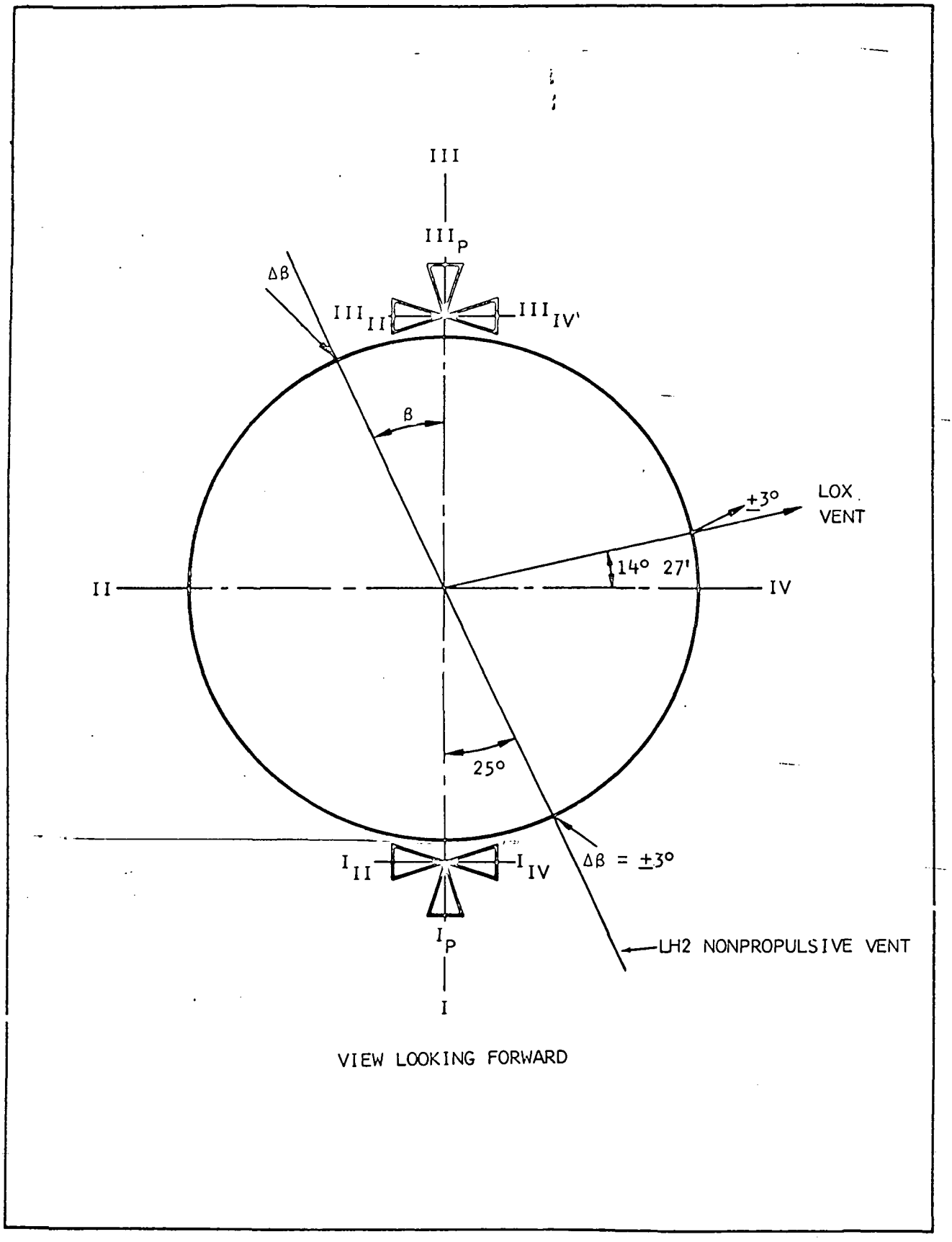

Figure 19-9. Auxiliary Attitude Control System and Vent Orientation

24 October 1966

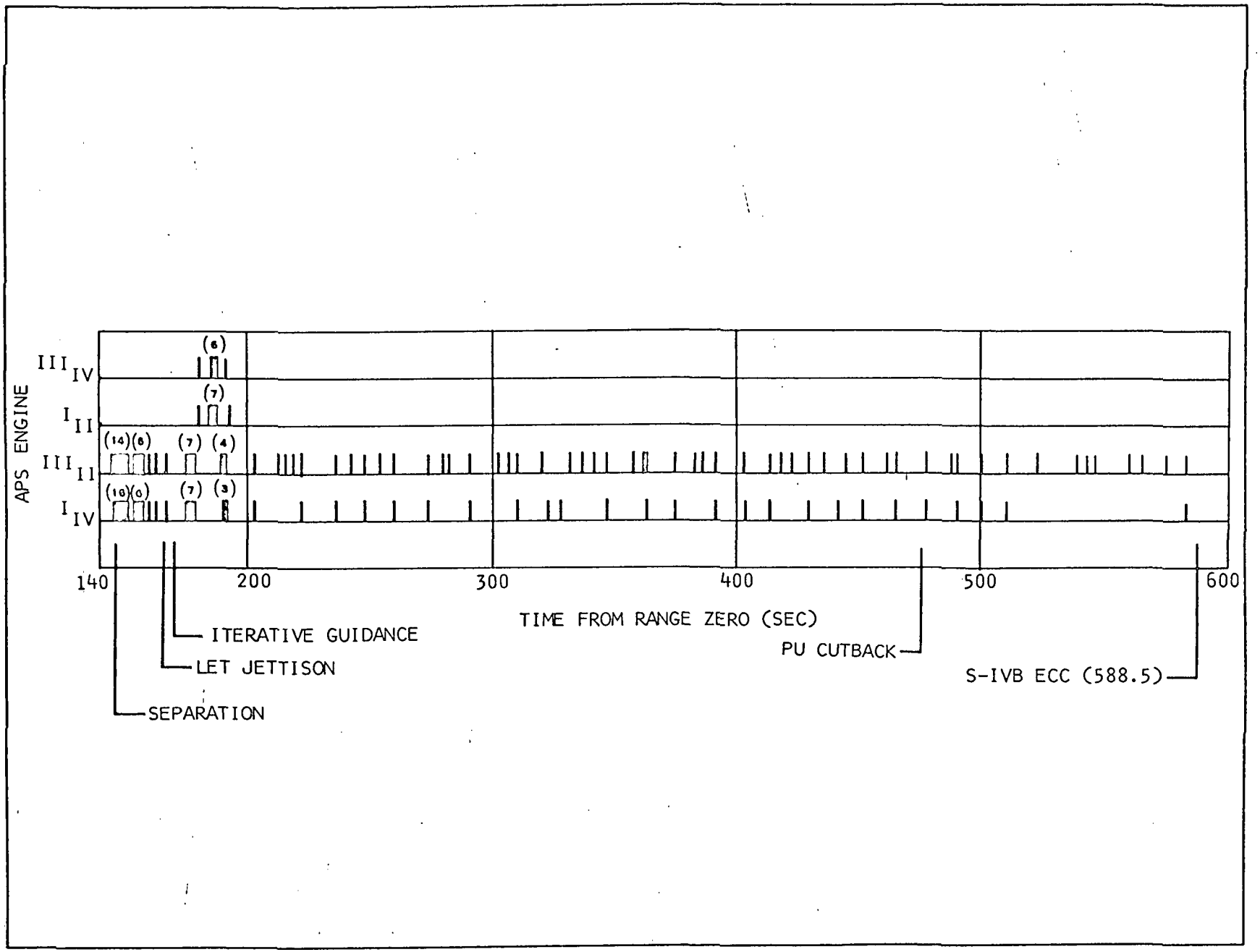

Figure 19-10. APS Firing History During S-IVB Powered Flight

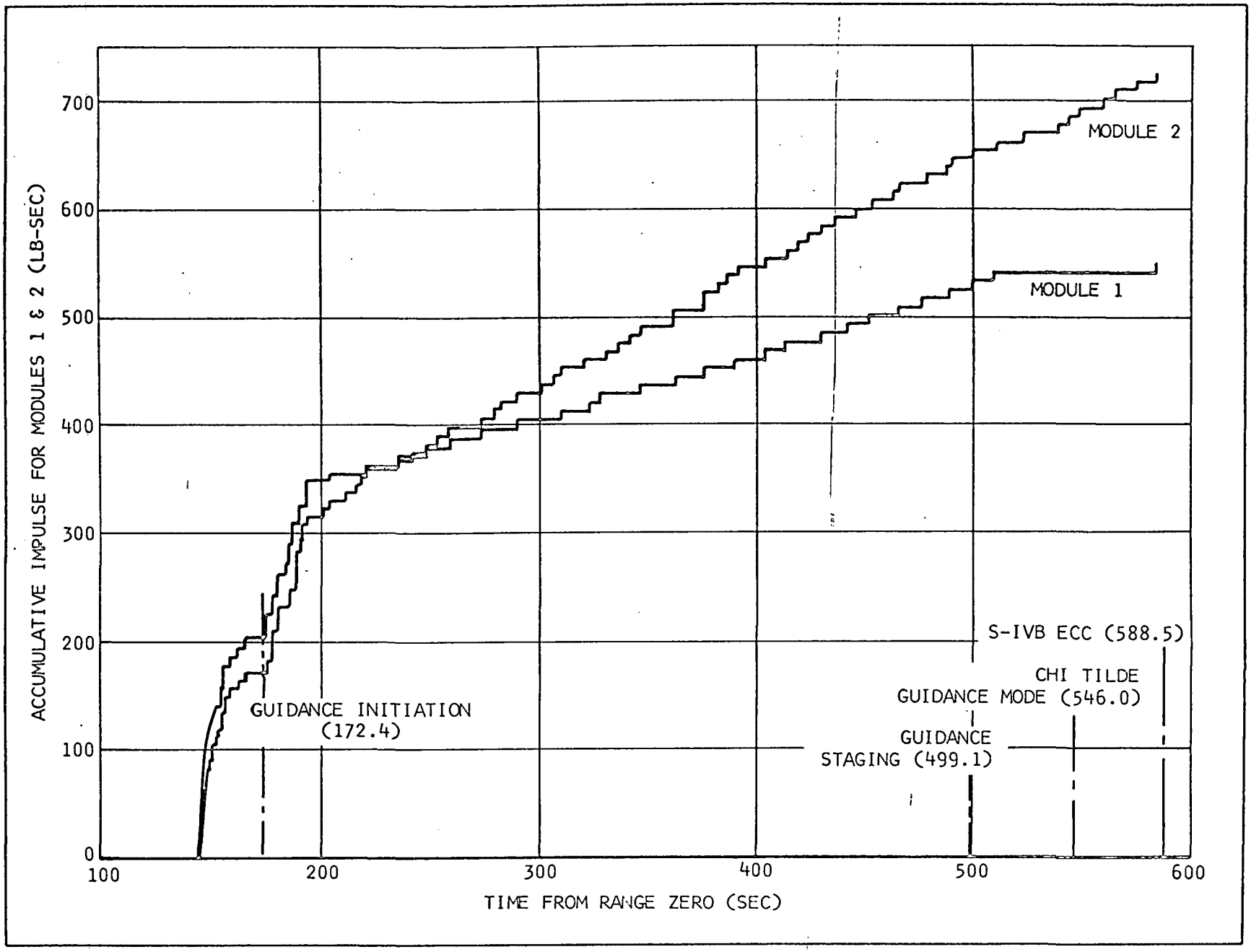

Figure 19-11. Total Roll Impulse for S-IVB-202 Powered Flight

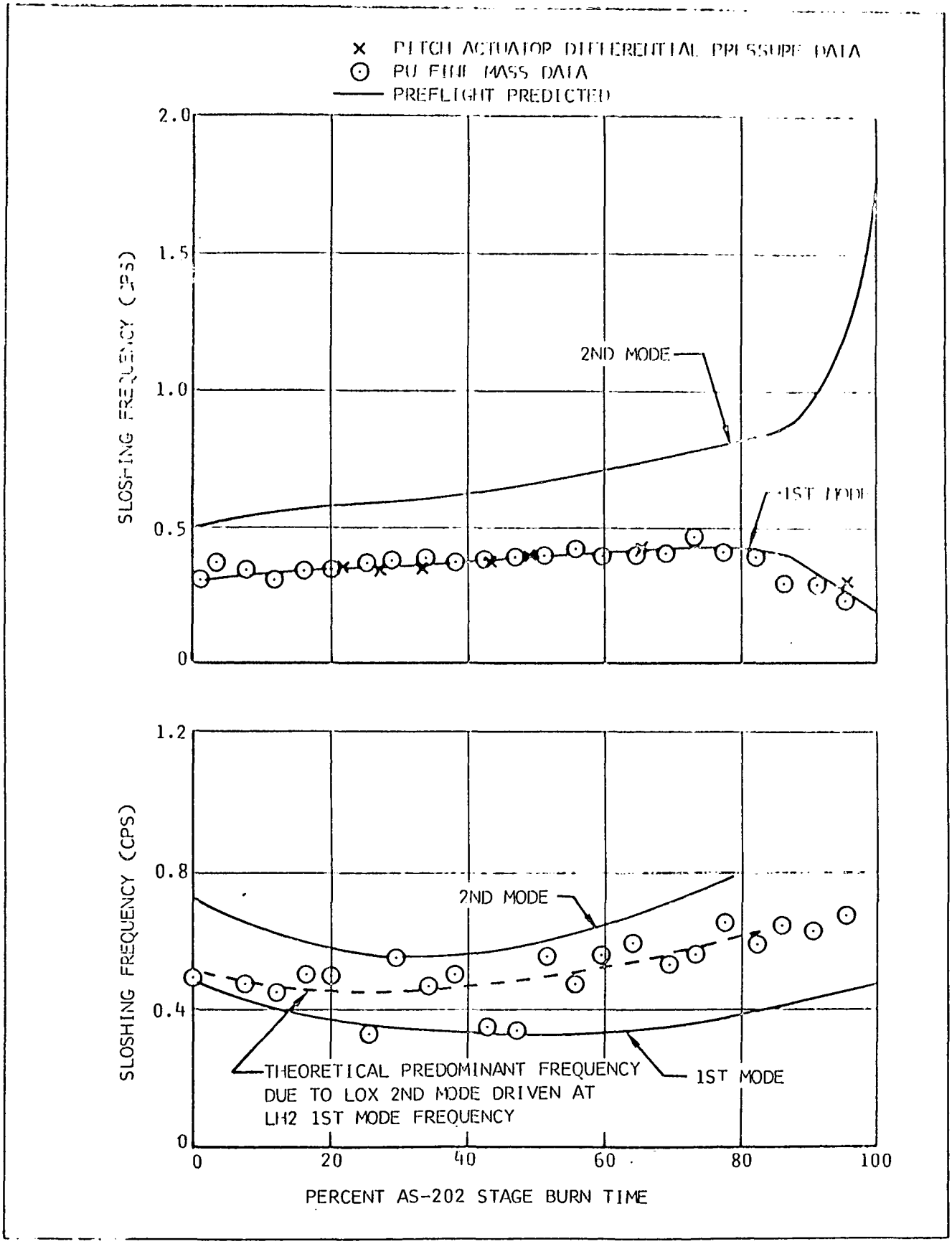

Figure 19-12. LOX and LH2 Slosh Frequency

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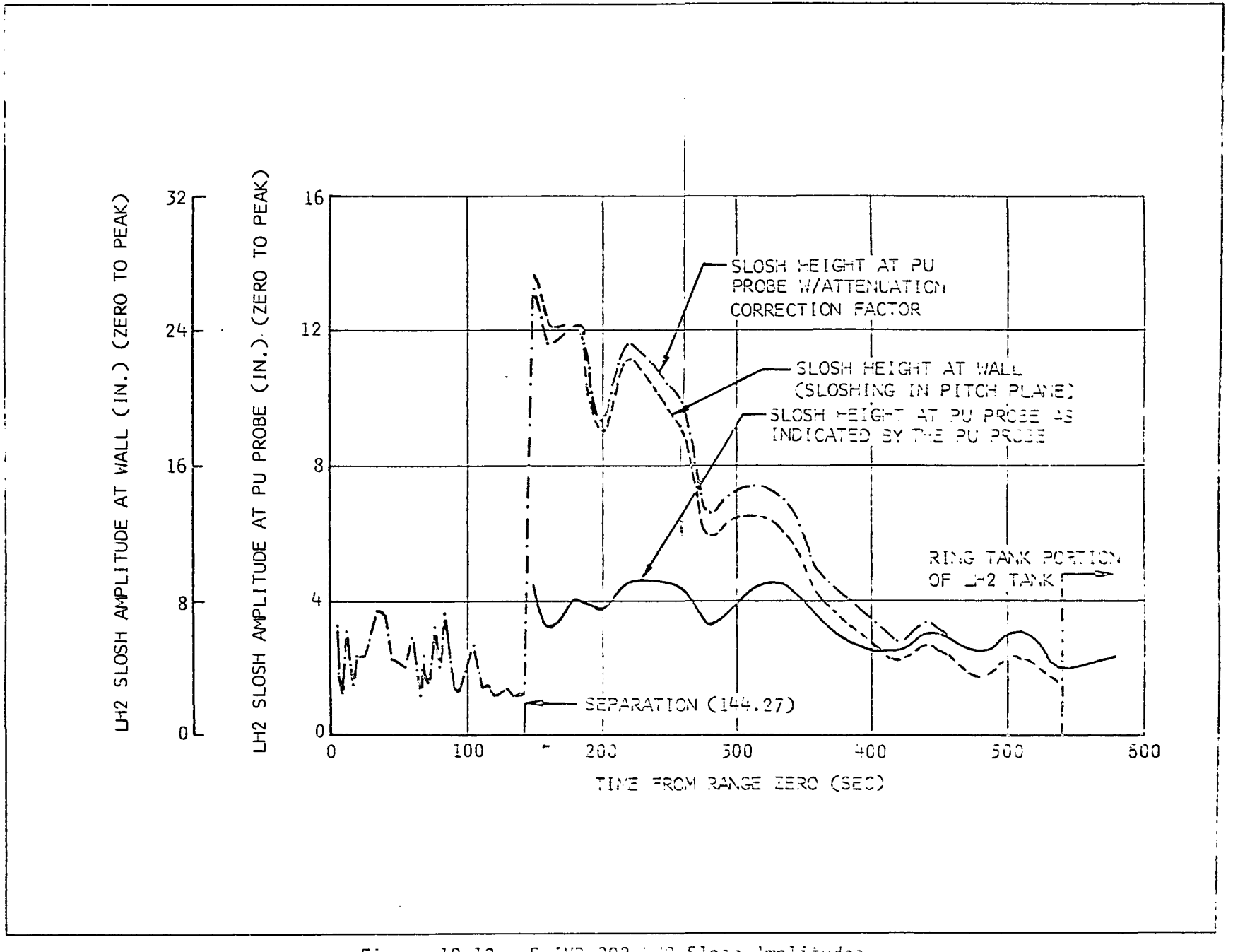

Figure 19-13. S-IVB-202 LH2 Slosh Amplitudes

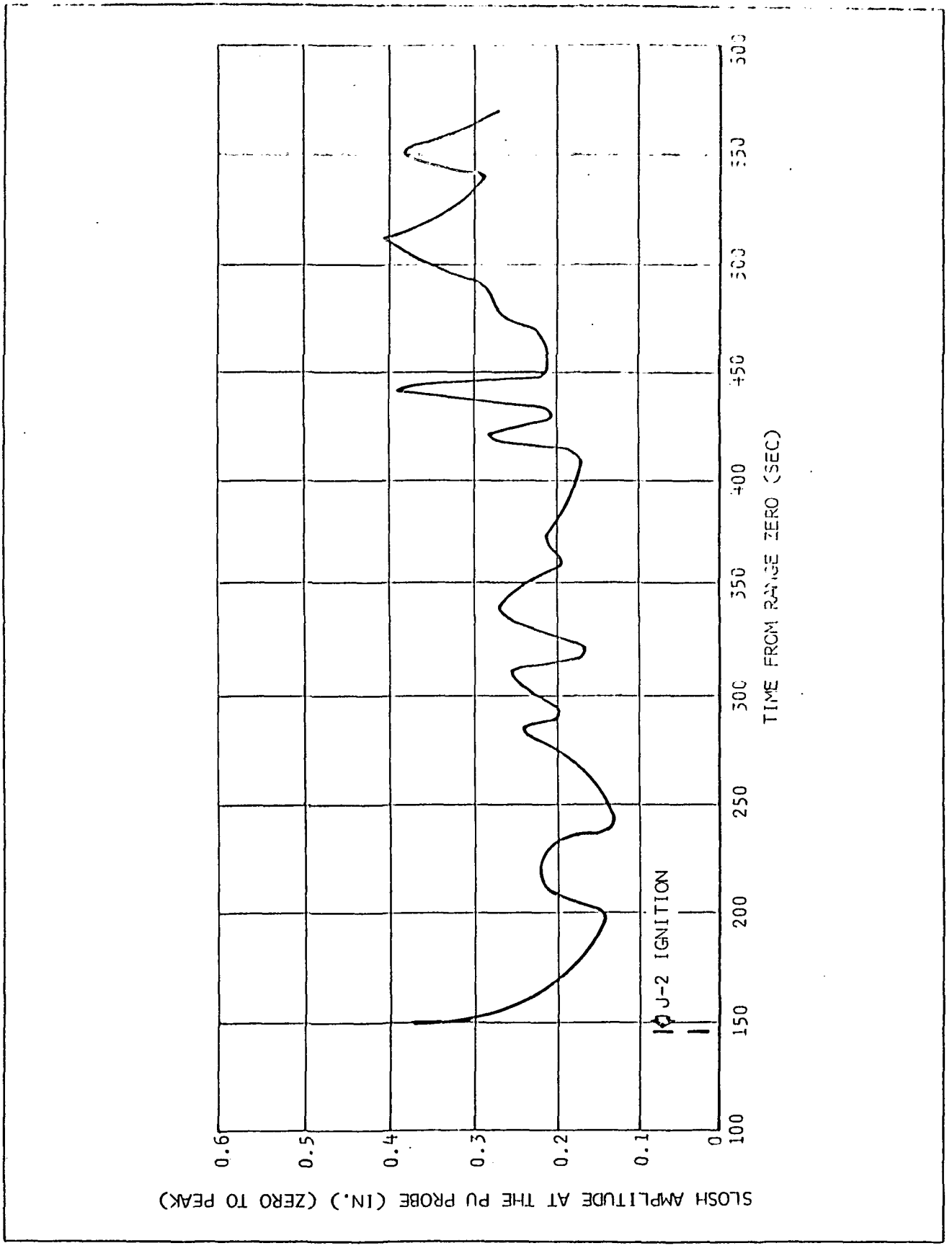

Figure 19-14. LOX Slosh Amplitudes

20. HYDRAULIC SYSTEM

The hydraulic system performed satisfactorily throughout the flight. All system performance values were within predicted limits.

20.1 Hydraulic System Operation

Hydraulic system pressures, temperatures, and fluid level at liftoff, S-IVB start, and S-IVB cutoff are presented in table 20-I. Dual values at S-IVB start represent initial and stabilized values associated with the momentary expected overshoot at engine driven pump start. The reservoir level dual value at S-IVB cutoff shows the stable level prior to and subsequent to the system bleed-down (after auxiliary pump OFF following cutoff by 2.75 sec).

Continuous fluid temperatures and level from before liftoff to S-IVB cutoff are presented in figure 20-1. Fluid thermal expansion in the system was not sufficient to cause overboard venting. Post-cutoff temperatures, during the available data acquisition period, duplicated the trends expected and seen on previous flights.

20.2 Servo System Operation

Flight data indicated bias signals from the instrument unit (IU) were applied to the S-IVB pitch and yaw servo actuators during the S-IB burn mode and during the auxiliary propulsion attitude control portion of the flight. The erroneous signals caused the pitch and yaw actuators to be displaced from null +0.2 and -0.8 deg respectively. The same problem existed in previous flights. These signals were not present during the J-2 engine burn period and therefore did not result in any performance problems.

The S-IVB engine positioning servo actuators responded properly to their respective input command signals throughout flight.

Figure 20-2 is a plot of the servo actuator signal and position activity during S-IB/S-IVB separation, S-IVB engine start through iterative guidance, during the $\tilde{\chi}$ guidance mode and engine cutoff. Good correlation was observed between the DAC telemetry and the corrected NASA IU

actuator data. The initial transients at separation, as measured by the inflight tape recorder, produced a maximum change in actuator position of 2.0 and 1 deg in the pitch and yaw planes respectively. After the telemetry blackout period, the maximum deflection in the pitch and yaw planes was 0.4 and -1.7 deg respectively. Guidance commands caused maximum pitch and yaw engine deflections of 11.0 and -1.4 deg respectively.

Proper operation of the actuator dynamic pressure feedback mechanisms was indicated by the pitch and yaw actuator differential pressure traces. The data indicated the initial transient loads to be low.

TABLE 20-1
HYDRAULIC SYSTEM PERFORMANCE VALUES

MEASUREMENT	EVENT		
PRESSURES - PSIA	LIFTOFF	ENGINE START	ENGINE CUTOFF
System oil	3,575	3,750/3,648	3,575
Accumulator GN2	3,600	3,780/3,625	3,610
Reservoir oil	166	184/176	174
Auxiliary pump air tank	408	409	424
TEMPERATURES - DEG F			
Main pump inlet oil	72	75	133
Reservoir oil	61	62	106
Accumulator nitrogen	33	32	33
Pitch actuator cylinder oil	28	28	44
Yaw actuator cylinder oil	31	32	47
LEVEL - PERCENT			
Reservoir oil	25.7	22/24.8	increased from 31.2 to 95.8

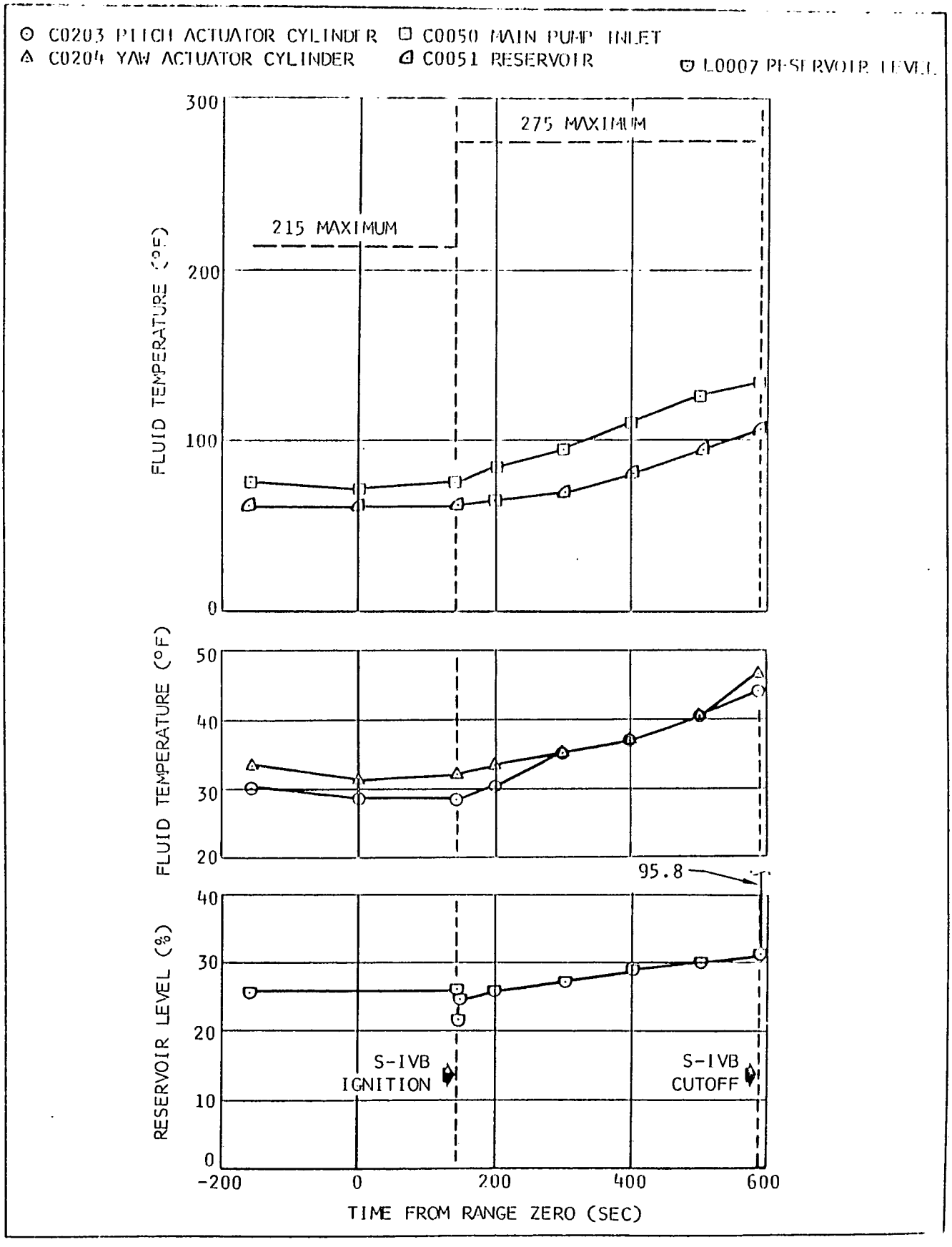

Figure 20-1. Hydraulic System Temperatures and Reservoir Level

24 October 1966

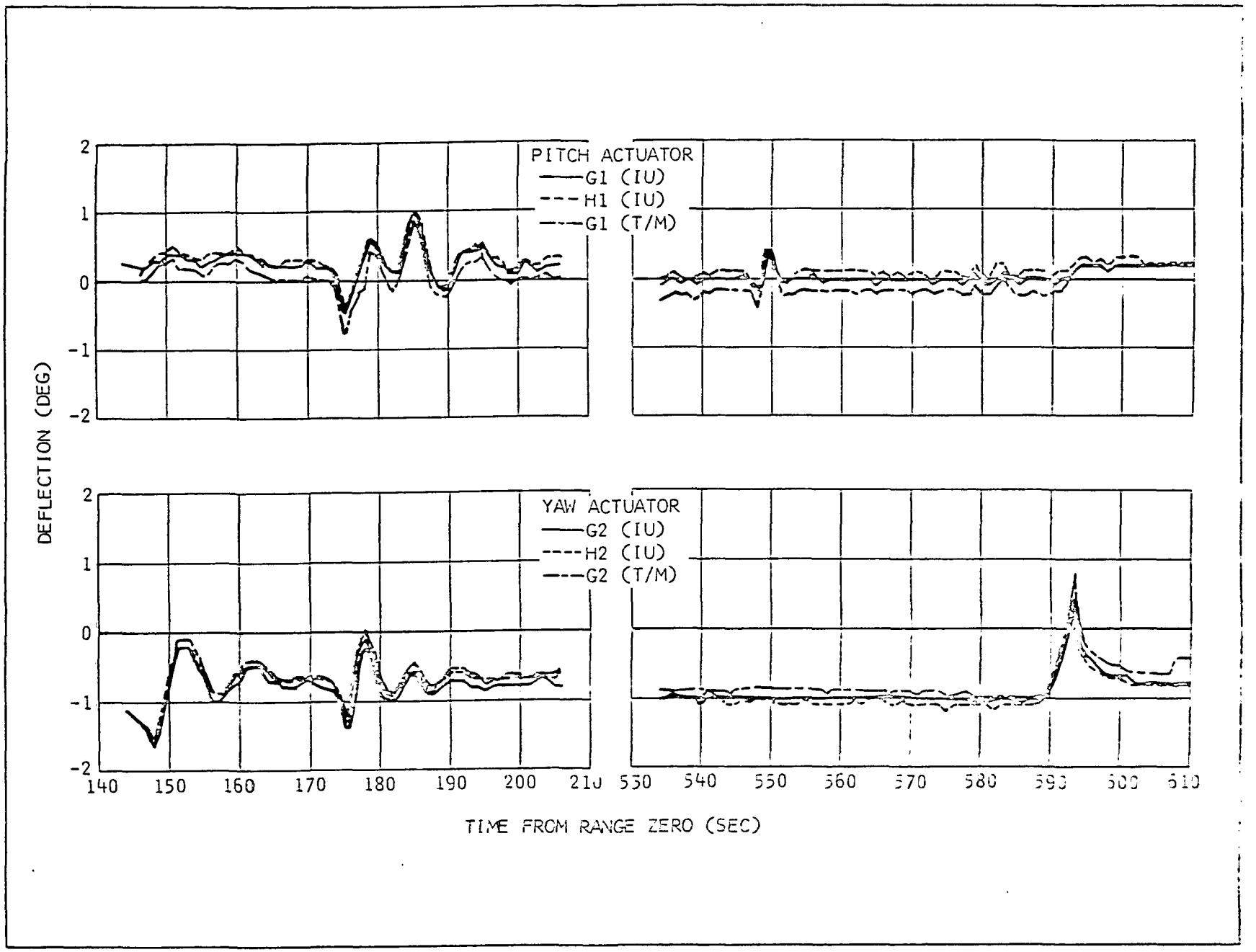

Figure 20-2. Pitch and Yaw Actuator Position

21. Stage Structure and Environment

An evaluation of strain, acceleration, pressure, and temperature data from the S-IVB stage indicated adequate structural strength existed for the conditions encountered in the AS-202 trajectory.

21.1 Flight Load Conditions and Structural Integrity

The flight conditions imposed on the S-IVB stage were less than the design conditions. At inboard engine cutoff (IECO), the measured axial acceleration of 4.08 g was 2 percent less than the design limit axial acceleration. During first stage powered flight, the S-IVB stage body bending moments were considerably less than the maximum predicted values because of the small wind shears and gusts encountered.

Measured skin differential bursting pressures on the forward skirt, aft skirt, and interstage were less than predicted values. No differential crushing pressures were indicated by the measurements. Recorded maximum temperatures of S-IVB stage structure subjected to aerodynamic heating indicated that flight temperatures did not exceed maximum predicted design temperatures. Propellant tank maximum ullage pressures and the common bulkhead pressure environment were as expected. The failure test of the common bulkhead at high altitude conditions gave results as predicted. The bulkhead test is described in paragraph 25.1 of this report.

21.1.1 Body Strains

Axial strain gages were installed on forward skirt stringers at sta 1586 and on aft skirt stringers at sta 1196 and 1260. Three measurement locations at each station, approximately 120 deg apart, permitted the calculation of maximum and minimum strains at the stations.

Erratic strain readings from strain gage measurement No. S0016, mounted to forward skirt stringer No. 14, were attributed to local thermal effects on the stringer. This stringer was adjacent to the LH2 vent valve and duct. The stringer apparently functioned as a heat source during LH2 tank fill and as a heat sink during aerodynamic heating. Other gages on the forward skirt appeared to be influenced to a much

lesser extent by thermal effects. Due to the lack of temperature gradient data at the stringers, where strain gages were located, it was not possible to separate thermally induced strains and flight load induced strains. Hence, vehicle bending moments and axial loads could not be computed from the strain data of the forward skirt.

The strain histories recorded for sta 1196 and 1260 of the aft skirt are presented in figures 21-1 and 21-2. From these measured strains, maximum and minimum strains were calculated and plotted. In addition, predicted maximum and minimum strain histories are presented for comparison. The measured strain data of both figures show similar amounts of average strain as compared to calculated strains for the measured flight liftoff axial acceleration of 1.1 g.

The predicted strain envelope for sta 1196 includes an axial load distribution of 80 percent load to the stringers and 20 percent load to the local axial intercostals, which is in accordance with the DAC detailed stress analysis of the aft skirt. Both predicted strain envelopes include tolerances of ± 7 percent for the telemetry system and ± 3 percent for the predicted engine thrust.

Measured and predicted strains are in general agreement. The measured strains indicate that only small aerodynamic gusts and wind shears were experienced during the AS-202 flight.

21.1.2 Axial Loads

The strain data measured for sta 1196 and 1260 during flight were used for computing axial load histories presented in figure 21-3. These histories are shown compared to preflight computed limit axial loads.

Longitudinal accelerations as measured in the forward skirt showed a maximum acceleration of 4.08 g at S-IB IECO. This is greater than the predicted axial load factor of 3.9 g, but less than the design limit axial load factor of 4.17 g at IECO.

21.1.3 Body Bending Moments

The strain data measured during flight was also used for computing bending moment histories, as shown in figure 21-4. These histories for sta 1196 and 1260 are shown compared to preflight computed limit moments. The preflight computed moment curve is a partial envelope covering the time of maximum αq and showing the total effect of a theoretical succession of wind shears and gusts. The curves show the S-IVB-202 stage was subjected to relatively small aerodynamic loading as compared to maximum expected values.

21.1.4 Pressure - Skirts and Interstage

The maximum calculated bursting pressure for the forward skirt during flight, based on pressure sensor measurements, was 1.20 psid at range zero (RO) +76 sec. This was substantially less than the maximum predicted bursting pressure of 2.86 psid at RO +65 sec. No differential crushing pressures were measured during flight, and none were predicted.

The maximum differential bursting pressure for the aft skirt and interstage from flight data was 0.68 psid at RO +81 sec. This was approximately one-half of the maximum predicted pressure of 1.32 psid at RO +76 sec for the AS-202 trajectory. No crushing pressures were developed at the aft skirt and interstage measurement locations.

21.1.5 Temperatures

A summary of maximum measured temperatures for the major structural assemblies subject to aerodynamic heating is given in table 21-1. Corresponding design temperatures are also shown. A comparison of values shows that flight temperatures did not exceed maximum predicted temperatures at the critical flight times indicated. This comparison supports other evidence that structural integrity was maintained.

21.1.6 LH2 and LOX Ullage Pressures

The maximum LH2 tank ullage pressure recorded in flight was 41.7 psia, whereas the prelaunch maximum recorded pressure was 37.5 psia. These values compare favorably with the limit design ullage pressure of 42 psia for the LH2 tank.

The maximum flight measured LOX tank ullage pressure of 41.8 psia, and the prelaunch maximum recorded pressure of 44.0 psia did not exceed the 44.0 psia LOX tank limit design pressure.

21.1.7 Common Bulkhead Pressure Environment

Prior to liftoff, the differential pressures across the common bulkhead ranged between 0 and +25.0 psid. A positive differential pressure occurs when the LOX tank ullage pressure exceeds the LH2 tank ullage pressure. During powered flight, the measured differential pressures ranged between -3.5 psid and +11.5 psid.

Following S-IVB engine cutoff, the LOX tank vent cycle was started. The LOX tank was vented for approximately 12 sec and then the vent was closed approximately 0.4 sec prior to spacecraft separation. The purpose was to reduce LOX tank pressure to preclude LOX tank relief venting during spacecraft separation. During the period between start of LOX tank vent and spacecraft separation, the differential pressure reached approximately -12.0 psid. However, this negative value is not typical and was obtained in the S-IVB-202 stage as a preliminary step to the subsequent buildup of additional negative differential pressure for the common bulkhead experiment. At approximately RO +941 sec the common bulkhead was deliberately failed under negative differential pressures as described in paragraph 25.1 of this report. The failure pressure was -32.5 psid, which exceeds the maximum ultimate design value of -30.7 psid. The common bulkhead internal pressure remained less than 1.0 psia throughout powered flight to verify the leak-tight construction of the bulkhead.

21.2 Explosive Ordnance Equipment

All exploding bridgewire (EBW) initiated ordnance systems performed as required. The stage separation system, which utilizes a dual mild detonating fuse (MDF) assembly, functioned on command and effected a complete disconnection of the S-IVB stage from the S-IB stage. The three ullage rockets and four retrorockets fired, thus accomplishing a normal separation sequence.

Approximately 12 sec following separation, the three ullage rockets and their fairings were jettisoned. This has been verified by telemetry data. The jettison indication was a drop to zero of the chamber pressure transducer bias voltage.

The safety and arming device, an element of the range safety system, was cycled electrically from ARMED to SAFE position several times during terminal countdown and functioned as required.

TABLE 21-1
MAXIMUM MEASURED TEMPERATURES OF MAJOR STRUCTURAL ASSEMBLIES
SUBJECT TO AERODYNAMIC HEATING

STRUCTURAL ASSEMBLY	*MEASURED MAXIMUM TEMPERATURE (°F)	TIME FROM RANGE ZERO (Sec)	**PREDICTED MAXIMUM TEMPERATURE (°F)	TIME FROM RANGE ZERO (Sec)	***EXTERNALLY INSULATED STRUCTURE
Forward Skirt	243	130	285	140	No
LH2 Tank Cyl. Wall	122	120	122	140	No
Aft Skirt	228	120	255	140	No
Interstage	146	120	255 (Uninsulated)	140	Yes

* Measured temperatures are adjusted for measurement lag due to mass of temperature sensors.

** Based on maximum heating trajectory

*** At location of temperature sensor.

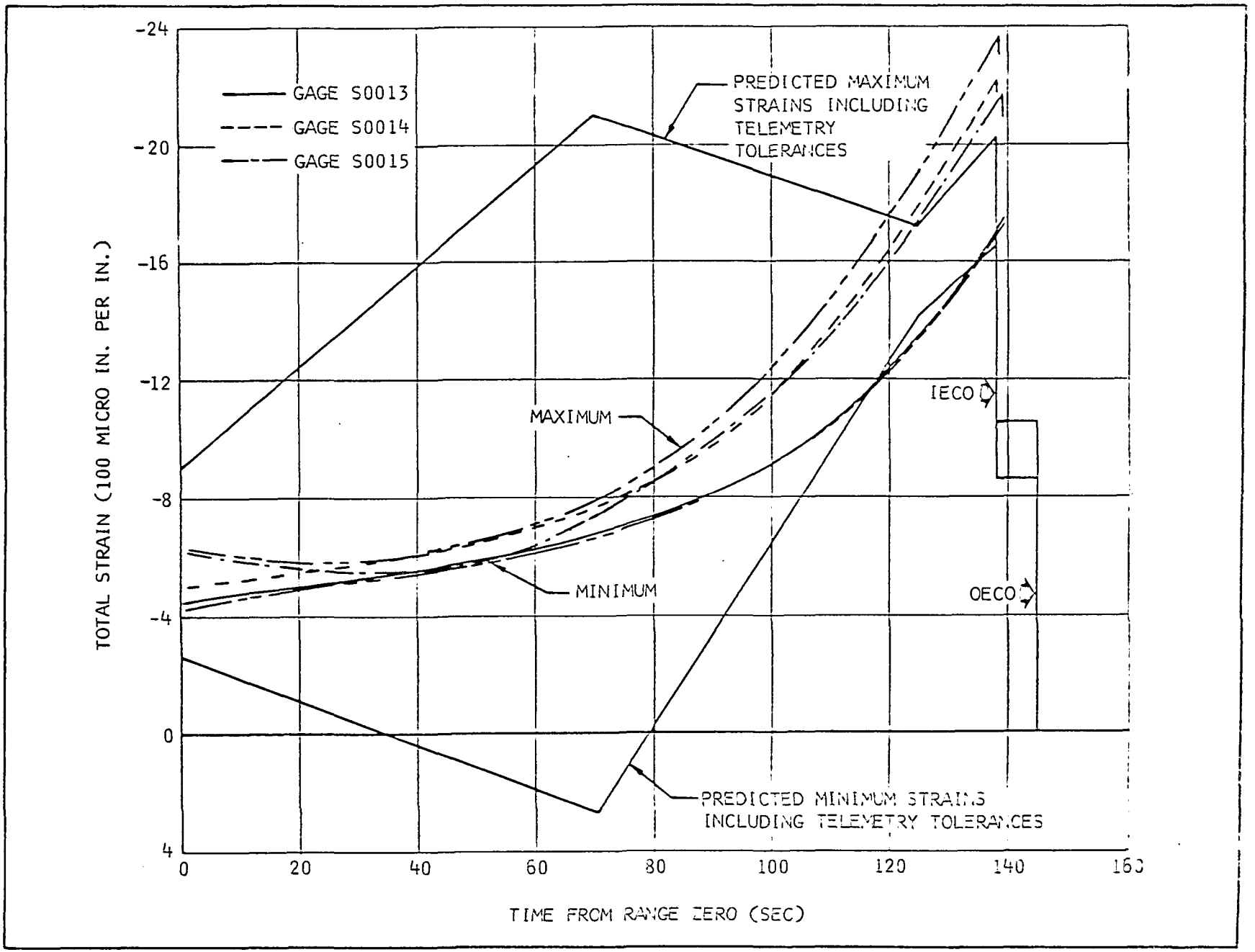

Figure 21-1. Axial Strain vs Flight Time, AS-202 Stage - Aft Skirt Sta 1136

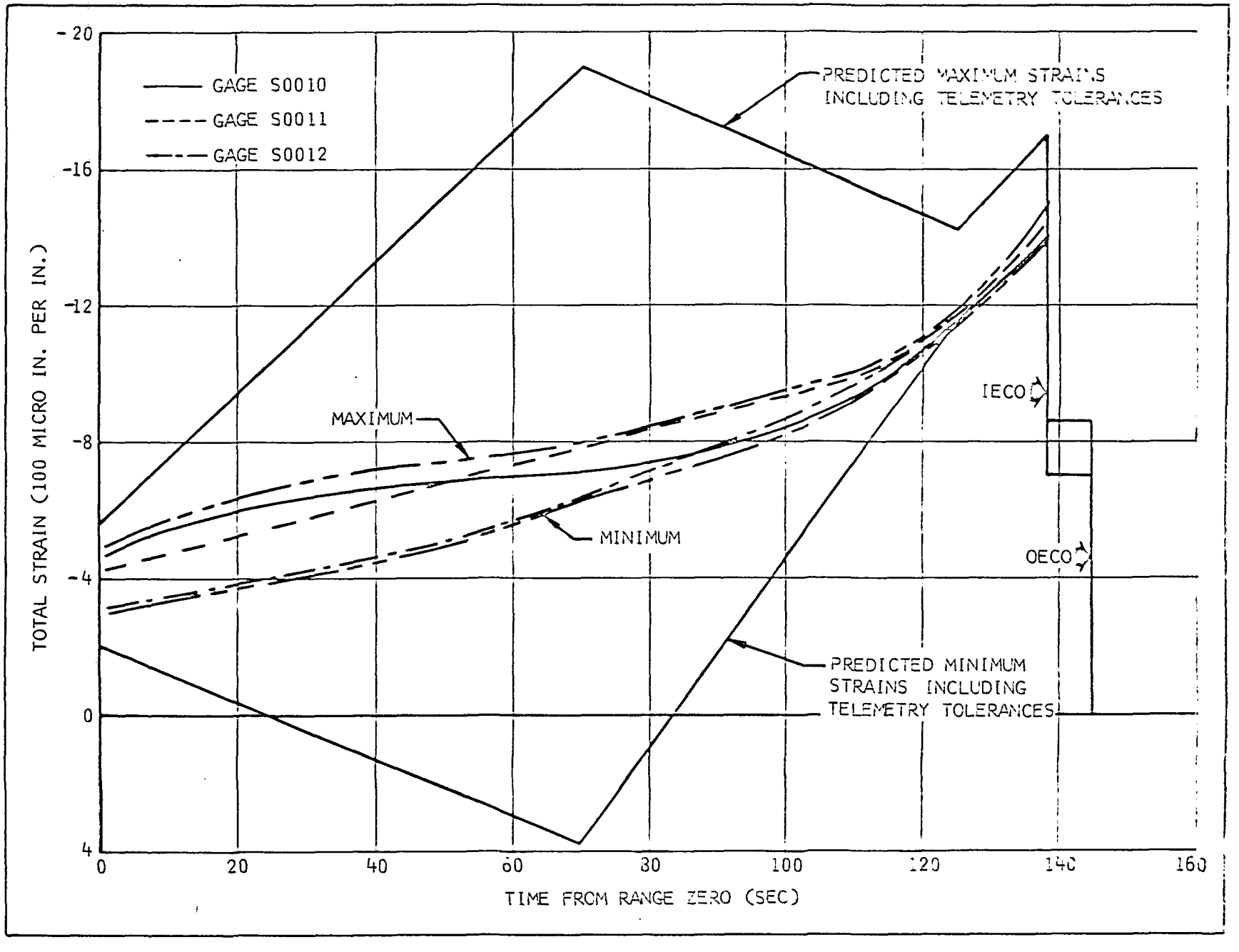

Figure 21-2. Axial Strain vs Flight Time, AS-202 Stage - Aft Skirt Sta 1260

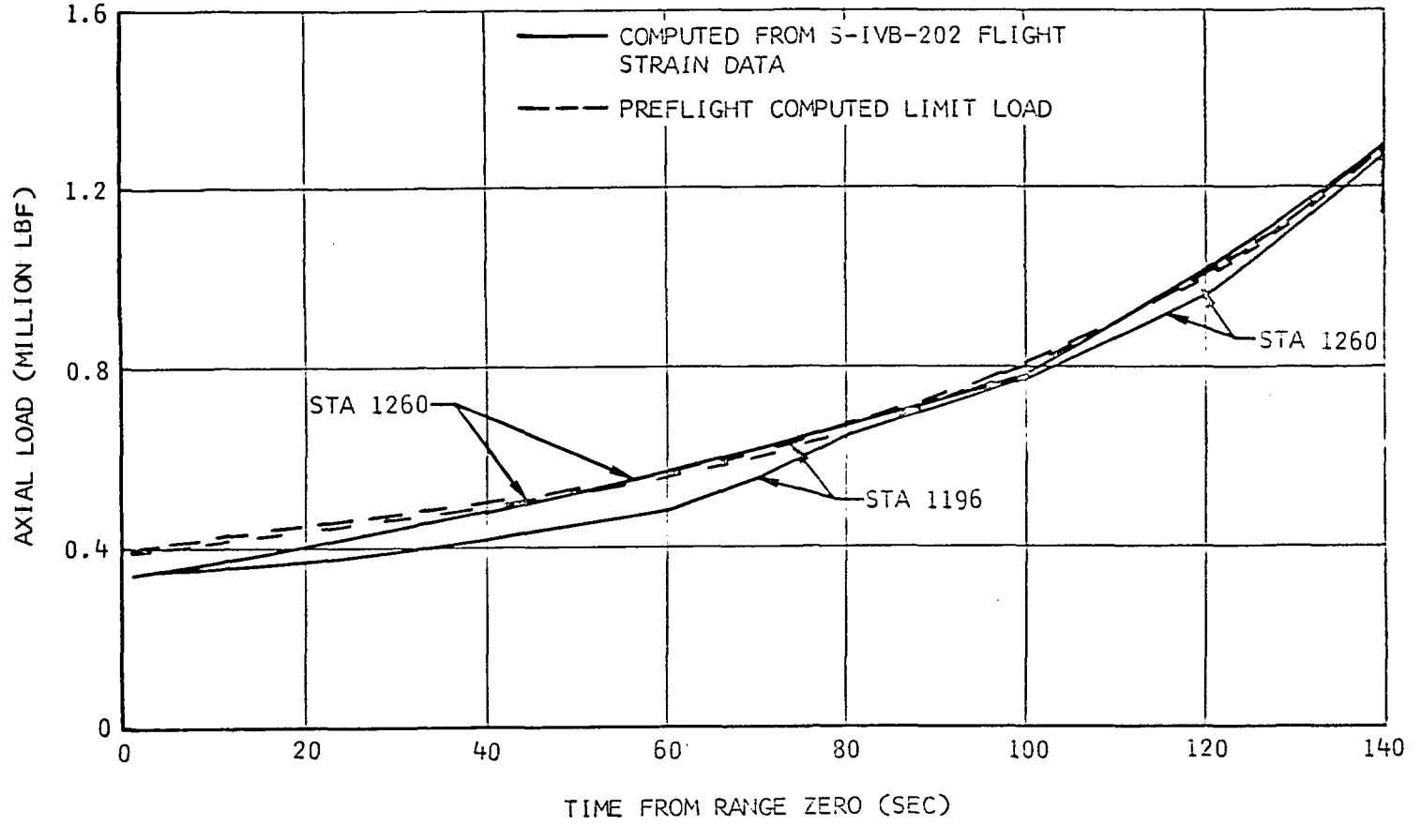

Figure 21-3. S-IB/S-IVB-202 Flight Axial Load vs Time, Sta 1196 and 1260

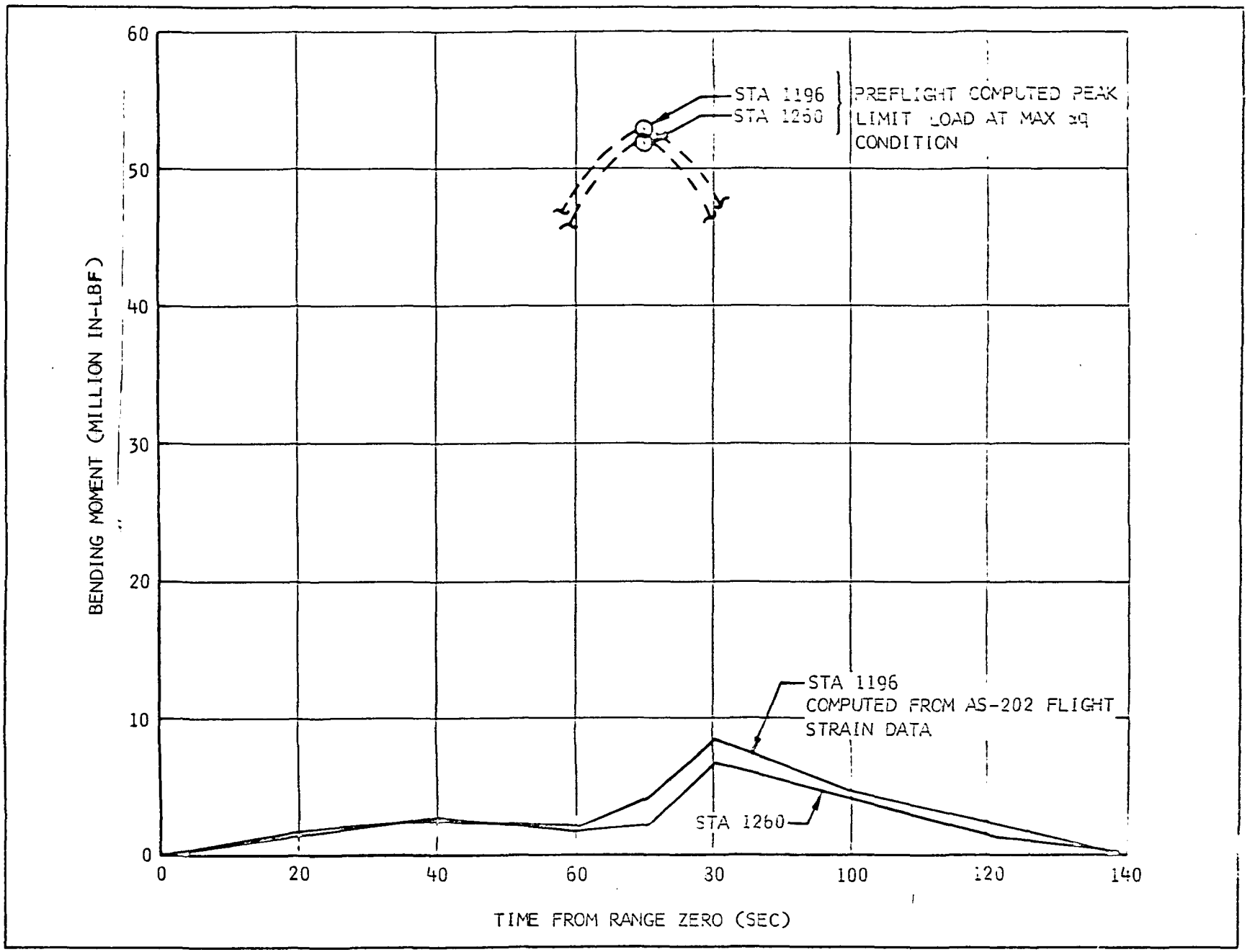

Figure 21-4. S-IB/S-IVB-202 Flight Bending Moment vs Time, Sta 1196 and 1260

22. FORWARD SKIRT THERMOCONDITIONING SYSTEM

The thermoconditioning system operated normally during flight and all temperatures, pressures, and flowrates were within design limits.

22.1 Temperature

The coolant temperature at the inlet to the cold plates (C0015) increased from 58.8 deg F at liftoff to a maximum of 62.1 deg F at R0 +20 sec (figure 22-1). The temperature decreased to 57.2 deg F by R0 +128 sec, then increased to 59.1 deg F at R0 +172 sec and stabilized at approximately that level.

The coolant outlet temperature (C0025) decreased from 61.1 deg F at liftoff until it dropped off scale at R0 +107 sec. The estimated minimum temperature reached is 58.6 deg F. After remaining off scale for 45 sec, the temperature increased to 61.4 deg F at R0 +400 sec, then decreased to approximately 60.9 deg F at R0 +630 sec. Temperature data was not available after this time.

22.2 Pressure

The coolant manifold pressure (D0017) stabilized at 44 psia and did not vary significantly from that value. The coolant outlet pressure (D0018) was 28.5 psia at liftoff and slowly increased to 30.2 psia by R0 +580 sec except for a single decrease to 28.0 psia at approximately R0 +150 sec.

22.3 Flowrate

The flowrate to the cold plates (F0010) was 8.6 gpm at liftoff; it increased to 8.7 gpm in the first 15 sec of flight, then gradually decreased to 8.3 gpm at R0 +600 sec.

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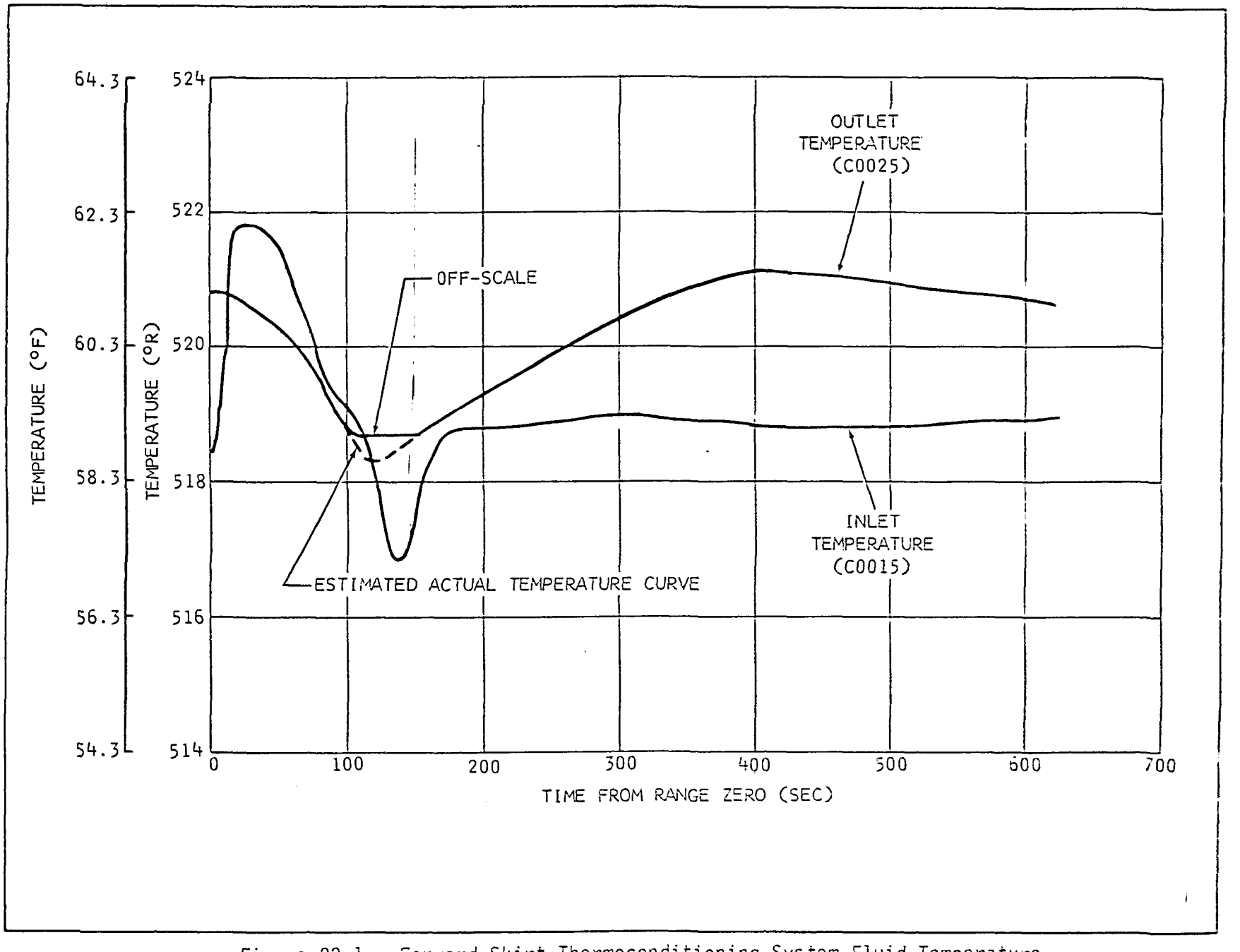

Figure 22-1. Forward Skirt Thermoconditioning System Fluid Temperature

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23. ACOUSTIC AND VIBRATION ENVIRONMENT

A total of 38 acoustic and vibration measurements were monitored on the S-IVB-202 stage and all provided usable data. Measurement locations were similar to the AS-201 flight.

In general, acoustic and vibration environments during the AS-202 flight were comparable to the AS-201 flight.

Vibration transients were noted after S-IVB engine cutoff. The excitation sources during this period were the S-IVB/spacecraft separation at approximately RO +599 sec and the plume impingement from the service propulsion system firing at RO +610 sec. These levels were lower than those measured during powered flight.

23.1 Data Acquisition and Reduction

There were a total of 32 vibration and 6 acoustic measurements monitored on the S-IVB-202 stage. A list of the measurements is presented in table 23-1 and the transducer locations are shown in figure 23-1.

Overall levels during specific flight periods are also presented in the table. For comparison purposes, the maximum levels measured during the AS-201 flight are presented.

Three separate telemetry systems were used to acquire the data: PAM/FM, FM/FM, and SSB/FM. The PAM/FM system, in conjunction with a filtering and averaging circuit, was used to provide high frequency (above 3,000 cps) acoustic data. The FM/FM system was used to provide low frequency (5 to 330 cps) vibration data. Both systems provided extended frequency information to supplement the data from the SSB/FM system which has a frequency range of 50 to 3,000 cps.

A time-sharing arrangement was utilized to obtain a greater number of measurements than the number of allocated data channels. This method of acquisition provided data for 3 or 6 sec for every 12-sec commutation period. Time-sharing, however, prevented the acquisition of maximum response amplitudes and specific events (liftoff, separation, etc.) for some of the measurements. The time-shared channels are reflected in the time-history plots by interpolated lines between the time intervals of the actual measured data.

The data from the FM/FM measurements were analyzed to twice the standard IRIG channel response by using a modulation index of 2.5 instead of the standard index of 5.0. This increase in frequency response was obtained at the expense of a decrease in signal-to-noise ratio. However, the data from these measurements were not degraded because of the high signal-to-noise ratio of the recorded data.

The data from the SSB/FM measurements were corrected for data acquisition system rolloff characteristics from 200 to 50 cps. This correction was accomplished by utilizing the preflight sinusoidal sweep calibration data. Corrections were also applied for data reduction filter rolloff characteristics. The corrections were applied to the spectrum plots and to the overall levels in table 23-1. Because there was no convenient way to correct the time-history plots, there may be discrepancies with the values in the table. The levels below 50 cps in the power spectral density (PSD) plots from the SSB/FM measurements are to be disregarded because the SSB/FM system does not provide valid data below this frequency.

Both analog and digital techniques were utilized in reducing the data. The final analysis consisted of root-mean-square (RMS) composite time-history, one-third octave band, and PSD plots (figures 23-2 through 23-35).

23.2 Vibration Environment

The vibration environment was produced by acoustical, aerodynamic, and mechanical excitation. The predominate sources were: the H-1 engine exhaust noise at launch, unsteady flow conditions during the transonic period of flight, boundary layer turbulence during the period of maximum dynamic pressure (max q), J-2 engine operation during S-IVB powered flight, staging transients at separation, ullage rocket jettison, and S-IVB engine ignition and cutoff. Twenty-eight vibration pickups were located on the S-IVB stage to determine the response amplitudes of the stage structure and components to these excitation sources.

For discussion purposes, the measurements were grouped into engine, thrust structure, aft skirt, and forward skirt measurements.

23.2.1 Engine Measurements

The engine vibration measurements were monitored at the LOX and LH2 turbopumps and on the pitch and yaw actuators. Accelerometers were mounted on the flanges located above the LOX and LH2 turbopump housings to measure vibration in the lateral direction. Each accelerometer system had a dual output capability. The signals were transmitted via the SSB/FM and FM/FM telemetry systems to provide high and low frequency data. Together, these measurements provided data from 5 to 3,000 cps.

The LOX turbopump vibration data are shown in figures 23-2 (5 to 330 cps data) and 23-3 (50 to 3,000 cps data). The vibration levels during the flight were within those measured on the AS-201 and 203 flights. The increase in level at approximately RO +500 sec correlates with the change in PU valve position.

The LH2 turbopump data are shown in figures 23-4 (5 to 330 cps data) and 23-5 (50 to 3,000 cps data). The data from these measurements were erratic from RO +170 to RO +575 sec. The erratic response was not attributed to turbopump characteristics but to an apparent temporary anomaly in the transducer/amplifier system. During the time from liftoff to RO +170 sec and RO +575 to S-IVB engine cutoff, the vibration data compared with those from the AS-201 flight.

The engine actuator environment was determined with three accelerometers mounted on each servovalve of the yaw and pitch actuators. The data are shown in figures 23-6 through 23-11. The vibration response at these locations was comparable to the AS-201 flight. The vibration during S-IVB stage powered flight showed intermittent modulation in amplitude. This phenomenon is illustrated by the unstable amplitudes in the time-history plots and was also observed on the AS-201 flight and acceptance firings.

23.2.2 Thrust Structure Measurements

Measurements were located at the attach points of the engine to the thrust structure to determine the vibration input to the engine during S-IB stage powered flight and the vibration input to the thrust structure from the engine during S-IVB stage powered flight.

The accelerometers were located at both actuator attach points, oriented in the axial direction, and on the gimbal block, oriented in the thrust, pitch, and yaw directions. The data from these measurements are shown in figures 23-12 through 23-16. The vibration levels at these locations were similar to those measured on the AS-201 flight. A low level vibration transient was noted at approximately RO +599 sec due to the S-IVB/spacecraft separation.

23.2.3 Aft Skirt Measurements

The aft skirt measurements were located at two vibration-isolated ambient panels to determine the vibration input and response of the panels. The input accelerometers were located on the intercostal at the intersection with the ring frame, to which the sequencer (panel No. 1) and switch selector (panel No. 2) panels were mounted. The response accelerometer was located on panel No. 2 next to the switch selector unit. The data from these measurements are shown in figures 23-17 through 23-22. The vibration environment of the panels was comparable to the AS-201 flight.

Vibration transients were measured at approximately RO +599 and RO +610 sec due to the S-IVB/spacecraft separation and plume impingement from the service propulsion system firing, respectively. The measured levels were lower than those measured during powered flight.

23.2.4 Forward Skirt Measurements

Eleven measurements were monitored on the forward skirt to determine the vibration environment of two vibration-isolated cold plate panels and the field splice ring frame. The accelerometers were located on the structure to which the PU electronic panel (panel No. 9) and telemetry rack (panel No. 8) were mounted. In addition, one accelerometer was located on panel No. 9 next to the PU electronic assembly. The data from these measurements are shown in figures 23-23 through 23-28. The measured levels were comparable to those from the AS-201 flight.

The accelerometers on the field splice ring frame were located midway between positions I and II and oriented in the thrust, radial, and tangential directions. The accelerometer system for the thrust and radial direction measurements had a dual capability and the signals were

transmitted via the FM/FM and SSB/FM telemetry systems. These measurements provided data from 5 to 330 cps and 50 to 3,000 cps, respectively. The field splice vibration data are shown in figures 23-29 through 29-33. The vibration was comparable to the AS-201 flight.

The measurements on the forward skirt indicated vibration transients at approximately RO +599 and RO +610 sec due to the S-IVB/spacecraft separation and plume impingement from the SPS firing, respectively. The measured levels were lower than those measured during powered flight.

23.3 Acoustic Environment

The acoustic environment was produced by the H-1 engine exhaust noise at launch, unsteady flow conditions during the transonic period of flight (near Mach 1), and by boundary layer pressure fluctuations during the period of maximum dynamic pressure. Two microphones were located on the S-IVB forward skirt near position II, approximately 11 in. aft of the field splice. One microphone was flush mounted external to the skirt and the other internal. Both transducer systems had a dual output capability and the signals were transmitted by the SSB/FM and PAM/FM telemetry systems. The SSB/FM measurements provided data from 50 to 3,000 cps and the PAM/FM measurements provided the RMS overall levels for the 7th (2,400 to 4,800 cps) and 8th (4,800 to 9,600 cps) octave bands. The data from the SSB/FM measurements are shown in figures 23-34 and 23-35, and the values from the PAM/FM measurements are tabulated in table 23-1 for specific flight periods.

The external sound pressure levels were nearly identical to those measured on the AS-201 flight. There were no indications of wind shear loading at this location as noted on the AS-201 flight.

The internal sound levels were slightly higher from liftoff to Mach 1 and lower thereafter. There was also a contrast in the spectrum shape of the noise level between the two flights. The lower levels after Mach 1 correlate with the lower atmospheric pressure at the microphone during this flight. There are no explanations for the difference in the levels from liftoff to Mach 1 and in the spectrum shape at the present time.

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TABLE 23-1 (Sheet 1 of 2)
COMPOSITE VIBRATION AND ACOUSTIC LEVELS

MEASUREMENT NUMBER	MEASUREMENT	DIRECTION	FREQUENCY RANGE (cps)	S-IB POWERED FLIGHT LEVELS		S-IVB POWERED FLIGHT LEVELS		AS-201 FLIGHT MAX LEVELS
				LIFTOFF	MAX INFLIGHT	AFTER S-IVB IGNITION	PRIOR TO S-IVB CUTOFF	
	VIBRATION			ACCELERATION Grms				
E0005-411	PU Electronic Panel	Thrust	50 to 3,000	5.4	4.4	0.2	N	4.7
E0006-411	PU Electronic Assembly	Radial	50 to 3,000	5.3	2.6	0.3	N	6.3
E0007-411	PU Electronic Panel	Radial	50 to 3,000	10.2	5.8	0.3	N	8*
E0008-411	Telemetry Rack	Thrust	50 to 3,000	4.6	3.5	0.4	N	4.5
E0009-411	Telemetry Rack	Radial	50 to 3,000	9.1	4.7	0.4	N	7*
E0010-411	Telemetry Rack	Tangential	50 to 3,000	5.1	4.3	0.4	N	4*
E0011-404	Sequencer Panel	Thrust	50 to 3,000	9.3	2.8	1.2	N	6.9
E0012-404	Sequencer Panel	Radial	50 to 3,000	12.7	3.9	1.1	N	15*
E0013-404	Sequencer Panel	Tangential	50 to 3,000	16.1	6.9	1.4	N	15*
E0014-404	Switch Selector Panel	Thrust	50 to 3,000	10.4	5.9	0.7	N	14.3
E0015-404	Switch Selector Unit	Radial	50 to 3,000	5.1	2.1	0.5	N	9.2
E0016-404	Switch Selector Panel	Radial	50 to 3,000	9*	5.2	1.4	N	14.2
E0017-411	Field Splice	Thrust	50 to 3,000	3.7	2.3	0.2	N	3.2
E0018-411	Field Splice	Radial	50 to 3,000	12.4	5.5	0.3	N	9.3
E0019-411	Field Splice	Tangential	50 to 3,000	1.9	2.2	0.3	N	2*
E0020-403	Pitch Actuator Attach Point	Axial	50 to 3,000	1.2	0.8	2.7	2.6	2.5
E0021-403	Yaw Actuator Attach Point	Axial	50 to 3,000	1.2	0.8	2.3	2.3	2.5
E0081-401	LOX Turbopump	Lateral	5 to 330	0.4	0.3	1.2	2.4	1.4
E0082-401	LOX Turbopump	Lateral	50 to 3,000	1.2	0.8	12.9	30.9	19.3
E0083-401	LH2 Turbopump	Lateral	5 to 330	0.5	0.3	9.6	6.4	6.2

*Extrapolated Levels N - Noisy Data

TABLE 23-1 (Sheet 2 of 2)
COMPOSITE VIBRATION AND ACOUSTIC LEVELS

MEASUREMENT NUMBER	MEASUREMENT	DIRECTION	FREQUENCY RANGE (cps)	S-IB POWERED FLIGHT LEVELS		S-IVB POWERED FLIGHT LEVELS		AS-201 FLIGHT MAX LEVELS
				LIFTOFF	MAX INFLIGHT	AFTER S-IVB IGNITION	PRIOR TO S-IVB CUTOFF	
	VIBRATION			ACCELERATION Grms				
E0084-401	LH2 Turbopump	Lateral	50 to 3,000	1.1	0.7	25.9	28.5	21.8
E0085-411	Field Splice	Thrust	5 to 330	0.9	0.5	0.1	0.1	1.0
E0086-411	Field Splice	Radial	5 to 330	3.5	1.9	0.1	0.1	3.6
E0087-403	Gimbal Block	Thrust	50 to 3,000	0.9	0.5	3.1	3.4	3.7
E0088-403	Gimbal Block	Pitch	50 to 3,000	1.3	0.7	4.2	3.9	4.4
E0089-403	Gimbal Block	Yaw	50 to 3,000	1.2	0.7	3.0	4.2	3.9
E0175-403	Yaw Actuator Servo Valve	Axial	50 to 3,000	1.1*	0.5	5.2	4.0	3.1
E0176-403	Yaw Actuator Servo Valve	Radial	50 to 3,000	1.7	0.8	4.9	3.6	3.5
E0177-403	Yaw Actuator Servo Valve	Tangential	50 to 3,000	1.6*	0.7	4.7	3.3	2.1
E0178-403	Pitch Actuator Servo Valve	Radial	50 to 3,000	1.5	0.6	2.5	3.2	2.8
E0179-403	Pitch Actuator Servo Valve	Tangential	50 to 3,000	1.3	0.6	4.9	3.8	3.9
E0180-403	Pitch Actuator Servo Valve	Axial	50 to 3,000	1.6	0.7	6.7	5.9	5.9
	ACOUSTICS			SOUND PRESSURE LEVEL (db)				
B0001-411	Forward Skirt	Internal	2,400 to 4,800	117.5C	111.5C	NF	NF	119.0
B0002-411	Forward Skirt	Internal	4,800 to 9,600	113.0C	NF	NF	NF	115.5
B0003-426	Forward Skirt	External	2,400 to 4,800	136.5	135.5	NF	NF	138.0
B0004-426	Forward Skirt	External	4,800 to 9,600	131.0	132.0	NF	NF	130.5
B0005-411	Forward Skirt	Internal	50 to 3,000	145.3	134.1	NF	NF	143.8
B0006-426	Forward Skirt	External	50 to 3,000	150.4	148.6	NF	NF	151.0

*Extrapolated Levels C - Data Corrected for Background Noise NF - System Noise Floor

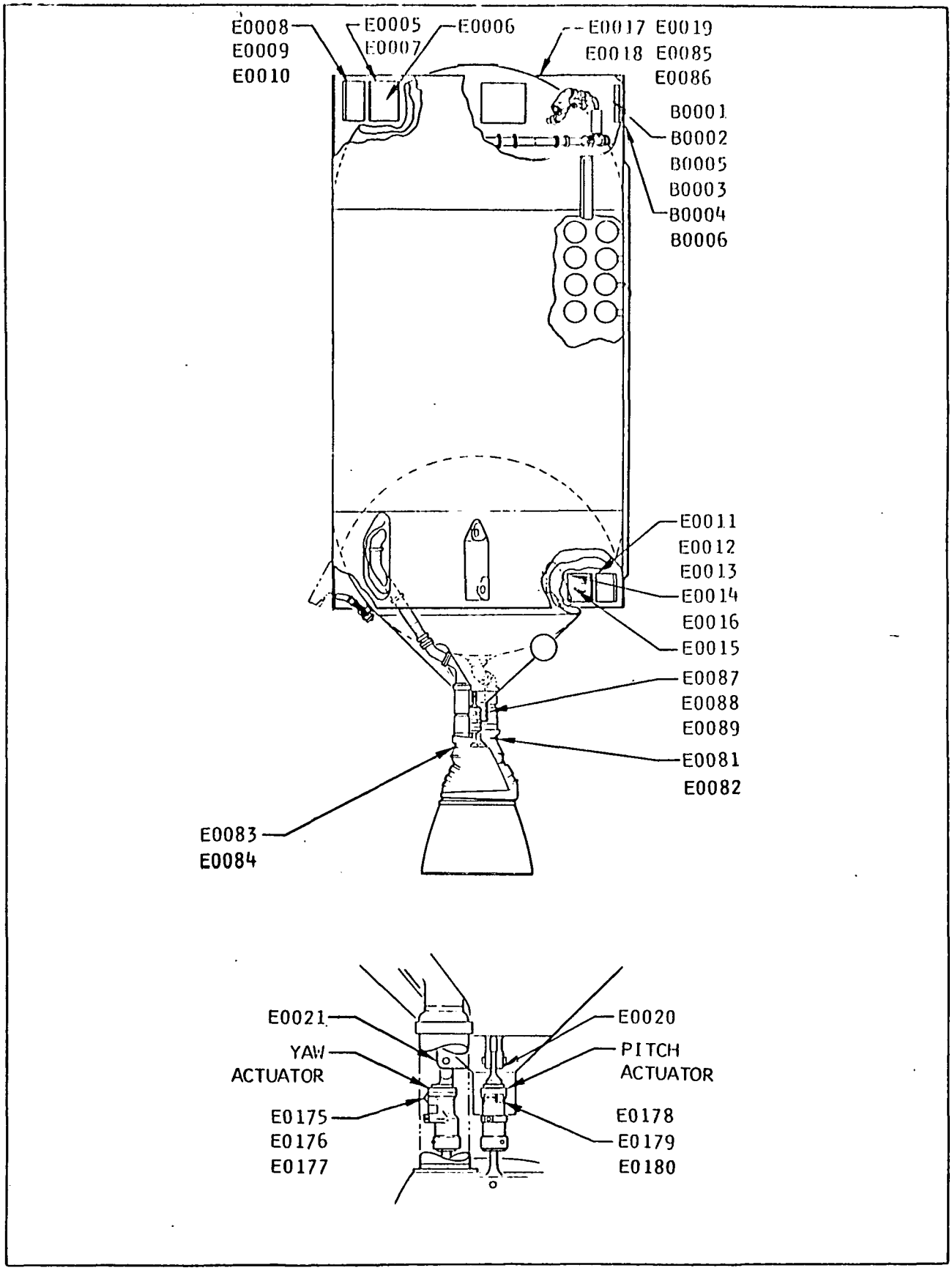

Figure 23-1. Acoustic and Vibration Measurement Locations

24 October 1966

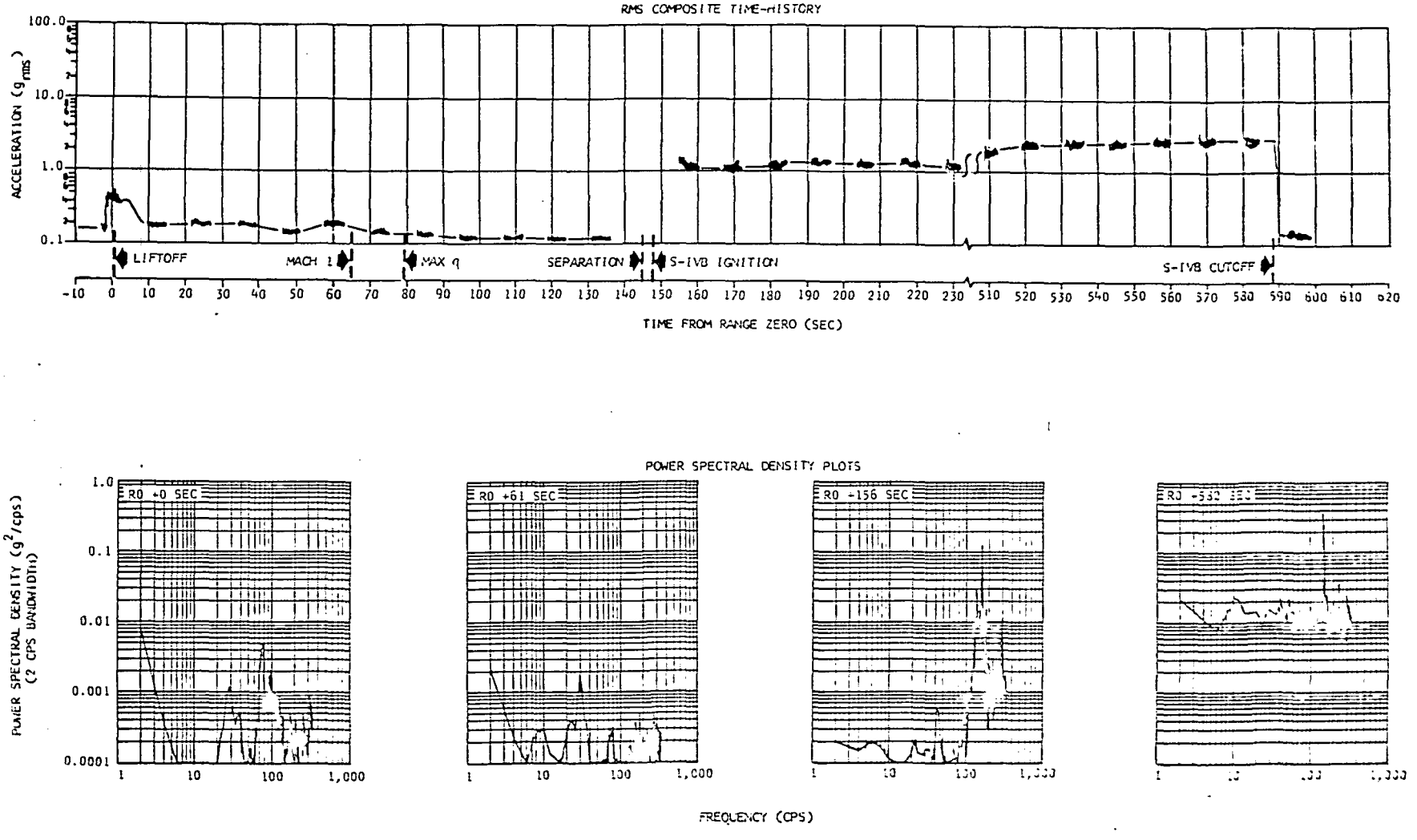

Figure 23-2. Low Frequency Vibration Measured at the LOX Turbopump, Lateral Direction (E0081-401)

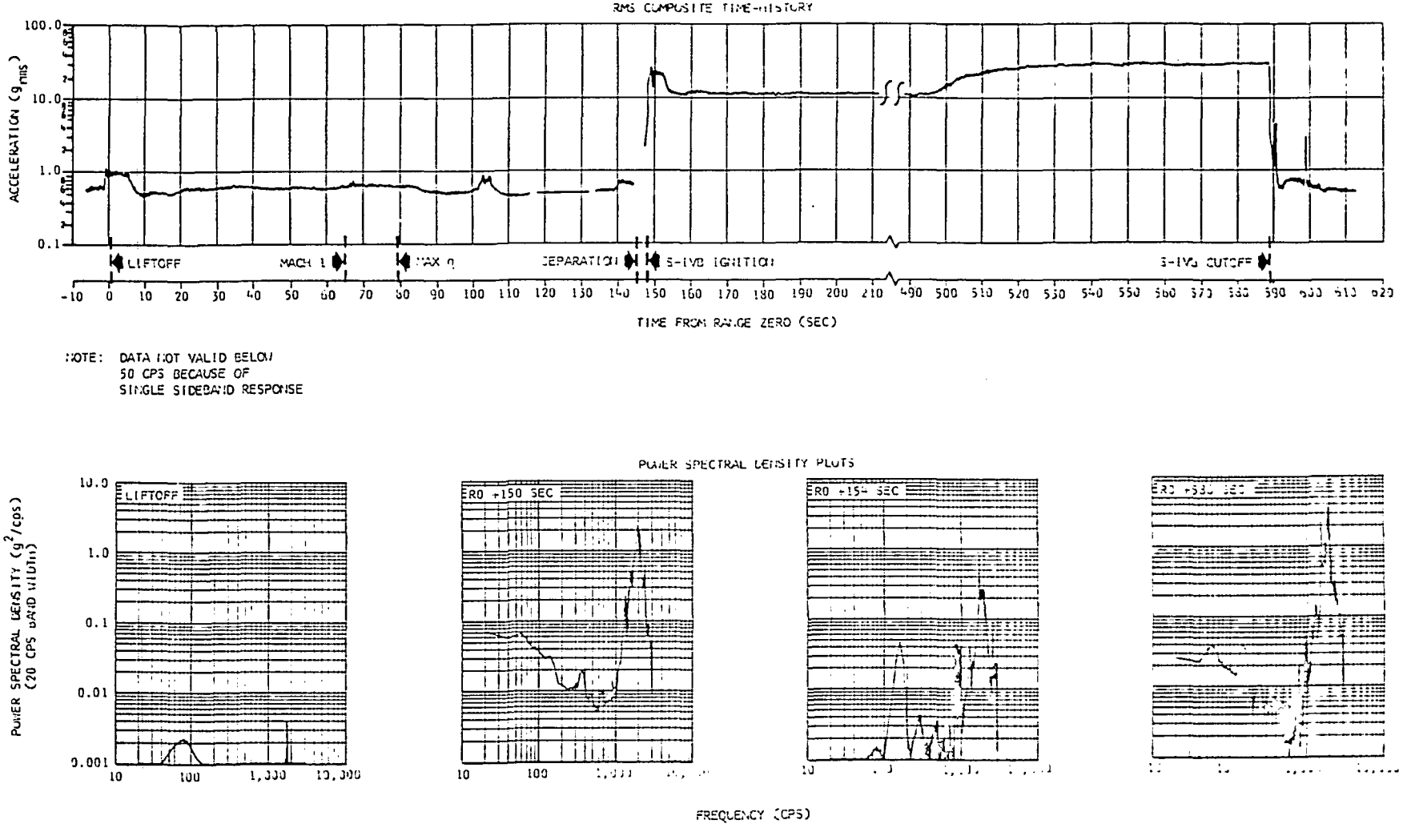

Figure 23-3. Vibration Measured at the LOX Turbopump, Lateral Direction (E0082-401)

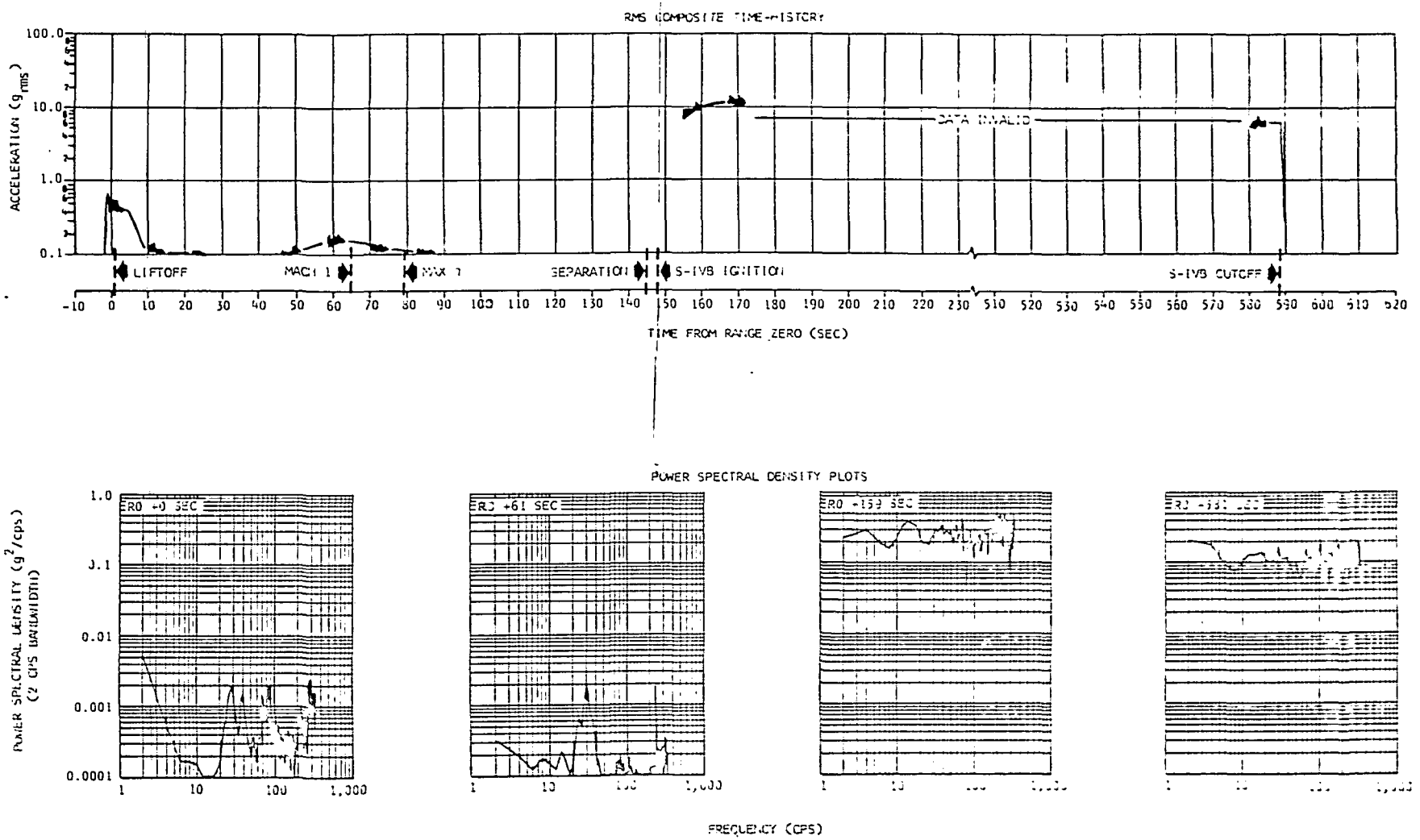

Figure 23-4. Low Frequency Vibration Measured at the LH2 Turbopump, Lateral Direction (E3083-401)

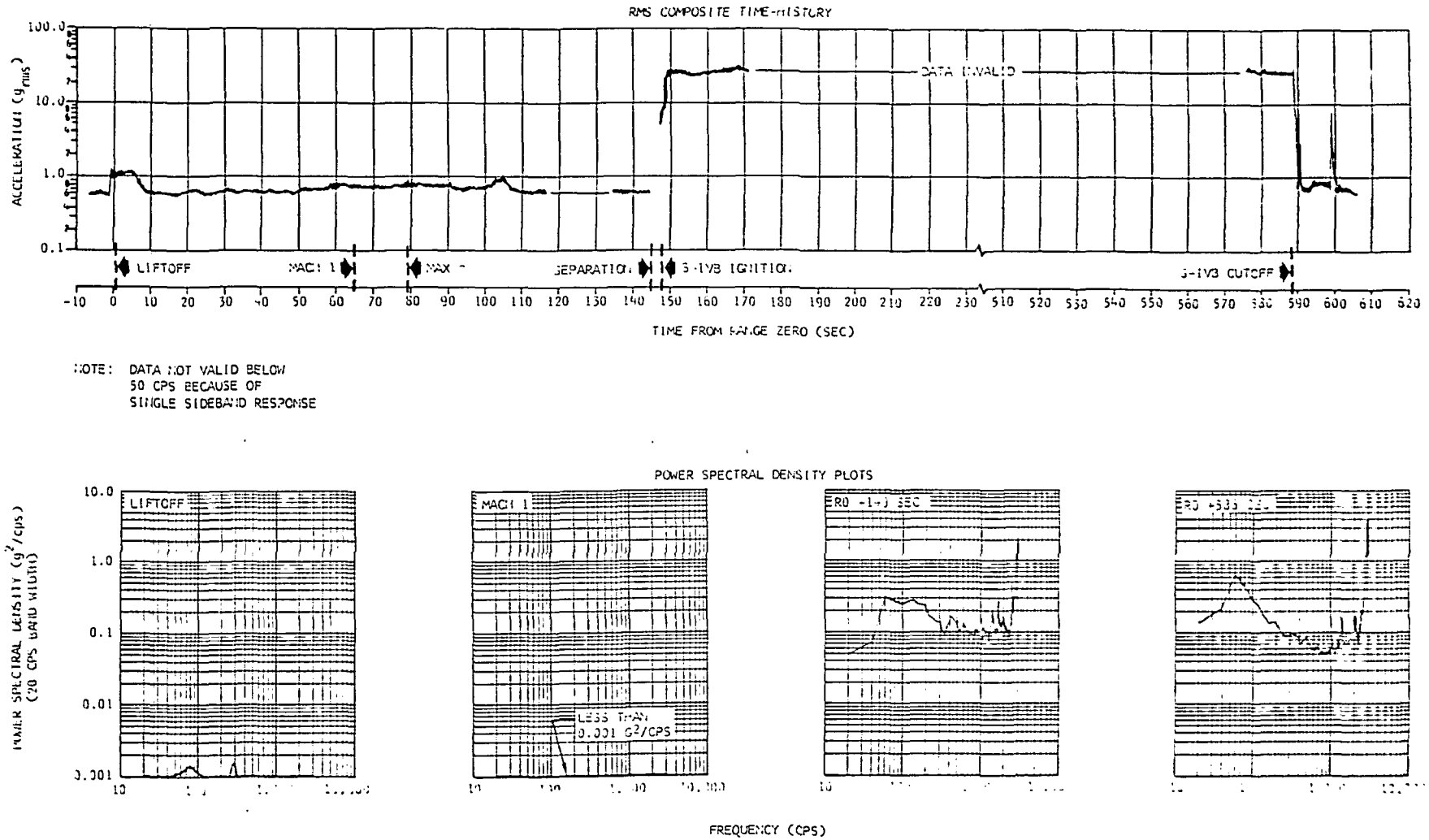

Figure 23-5. Vibration Measured at the LH2 Turbopump, Lateral Direction (E0084-4C1)

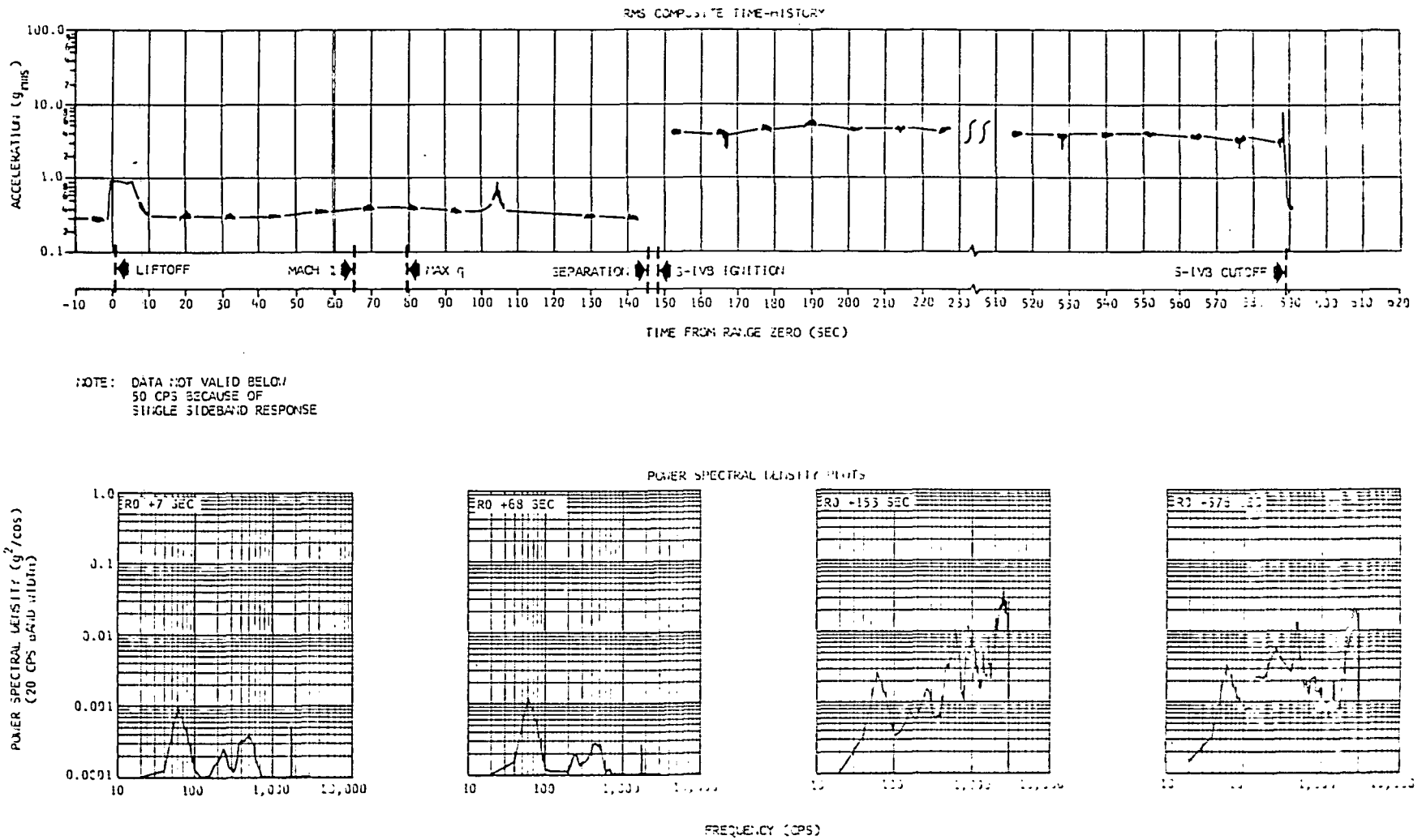

Figure 23-6. Vibration Measured on the Yaw Actuator Servo Valve, Axial Direction (E0175-403)

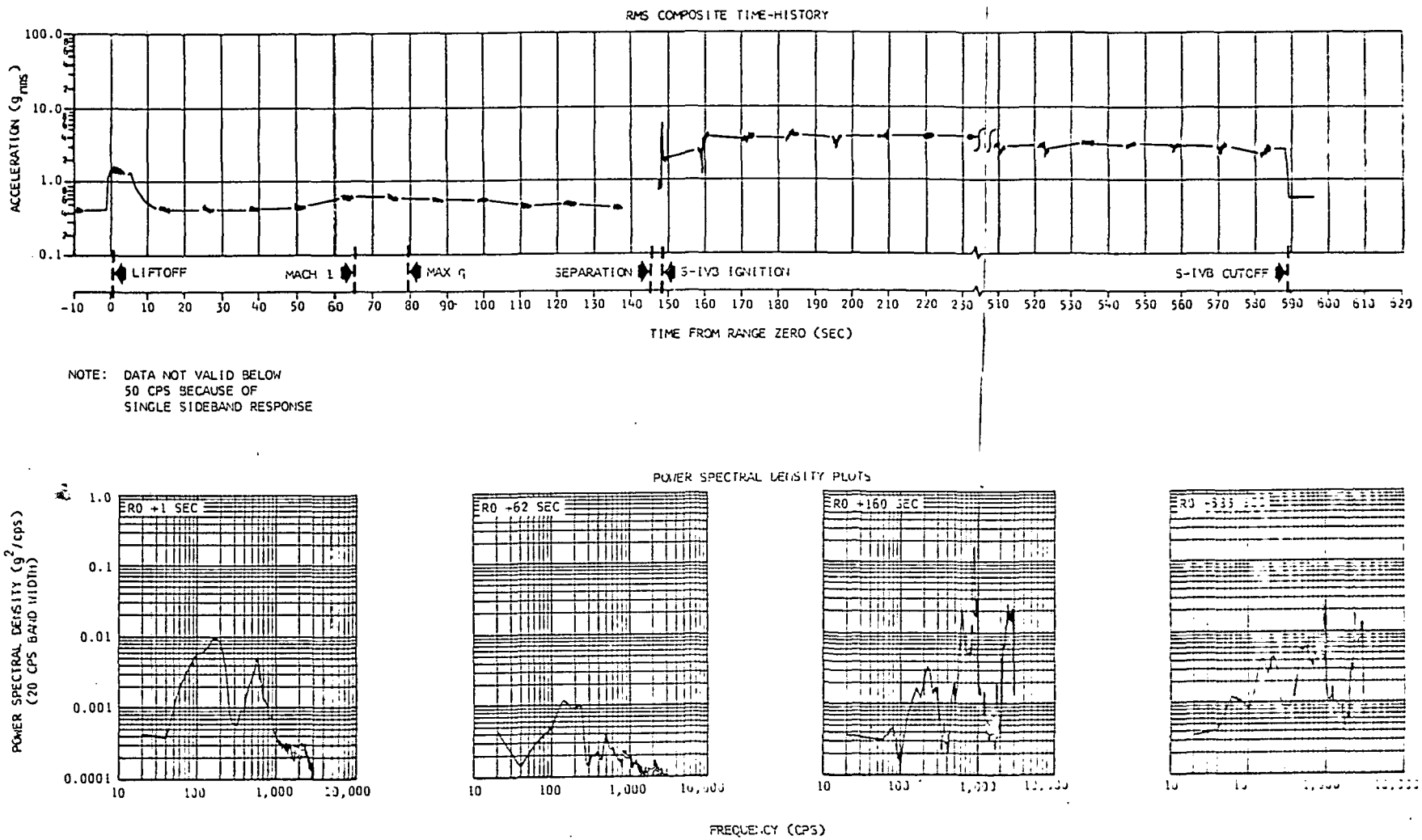

Figure 23-7. Vibration Measured on the Yaw Actuator Servo Valve, Radial Direction (E0176-403)

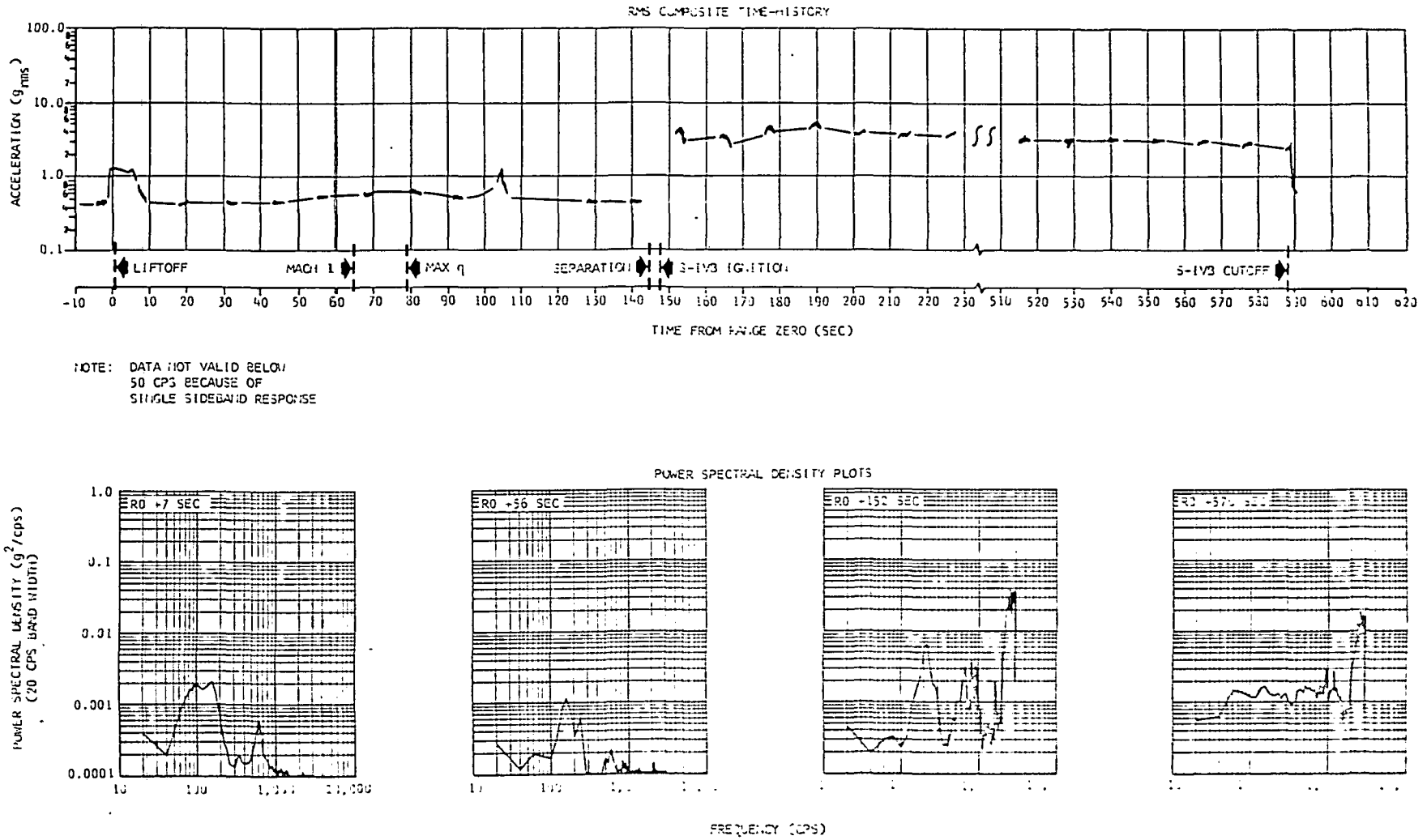

Figure 23-8. Vibration Measured on the Yaw Actuator Servo Valve, Tangential Direction (E0177-403)

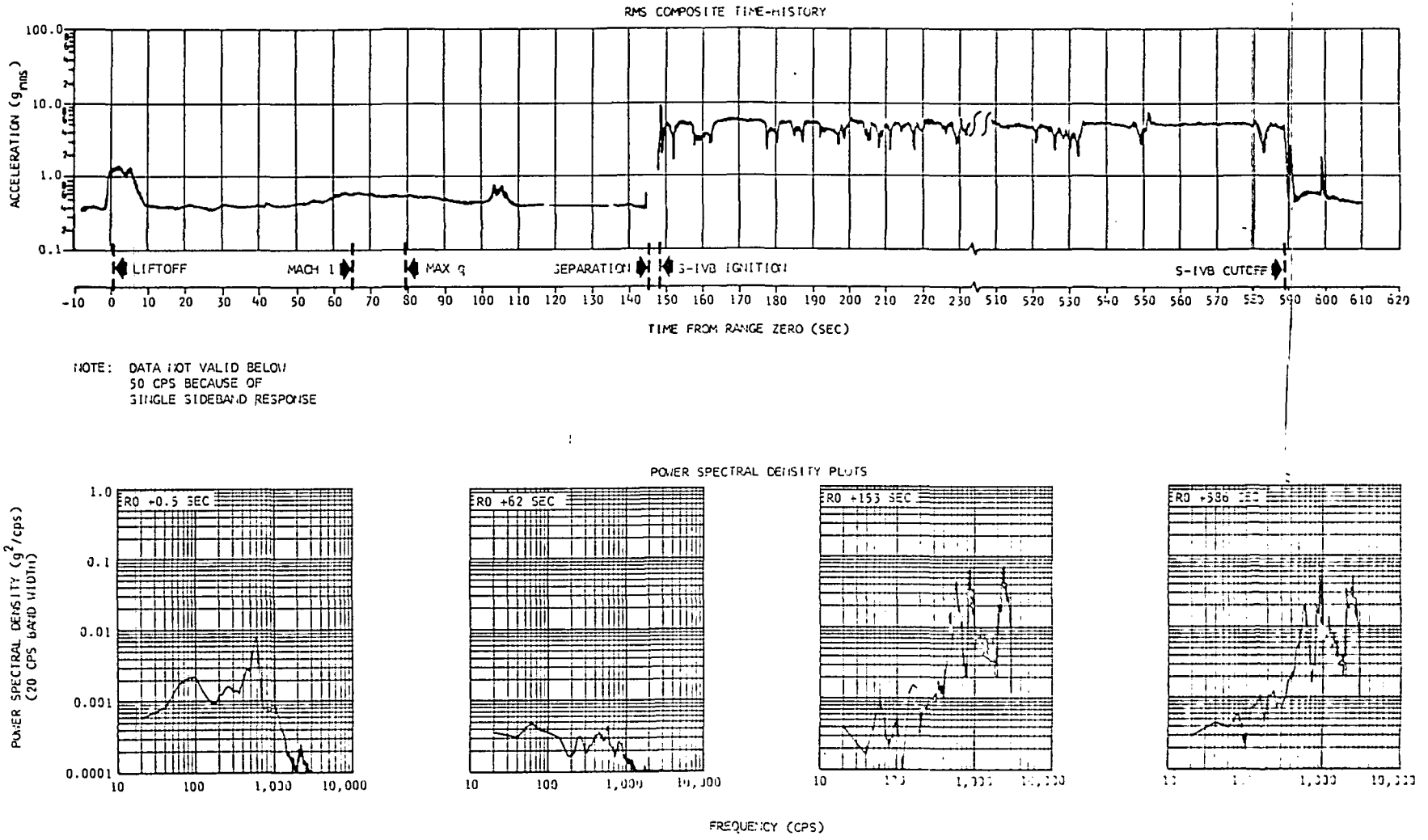

Figure 23-9. Vibration Measured on the Pitch Actuator Servo Valve, Axial Direction (E180-403)

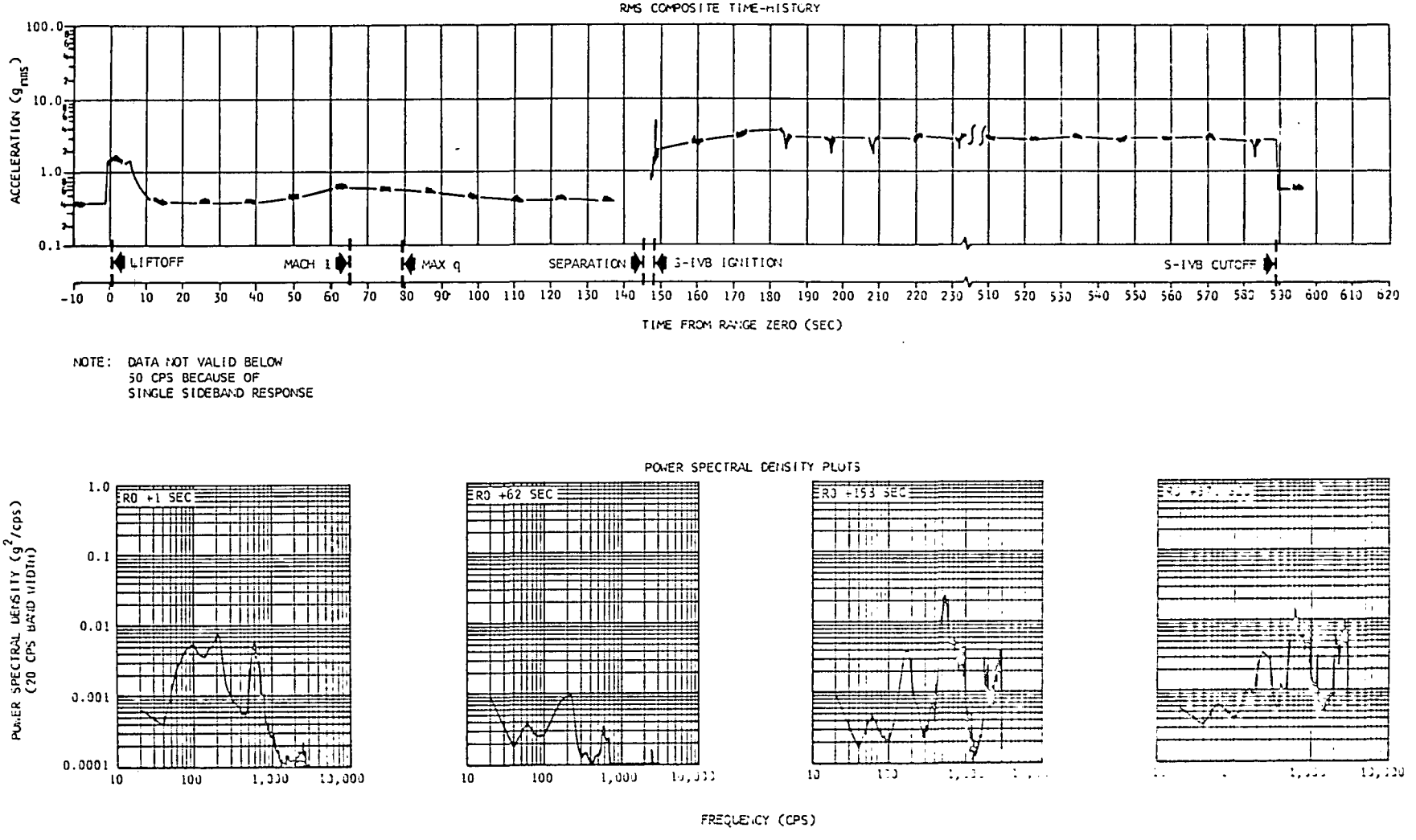

Figure 23-10. Vibration Measured on the Pitch Actuator Servo Valve, Radial Direction (EC178-403)

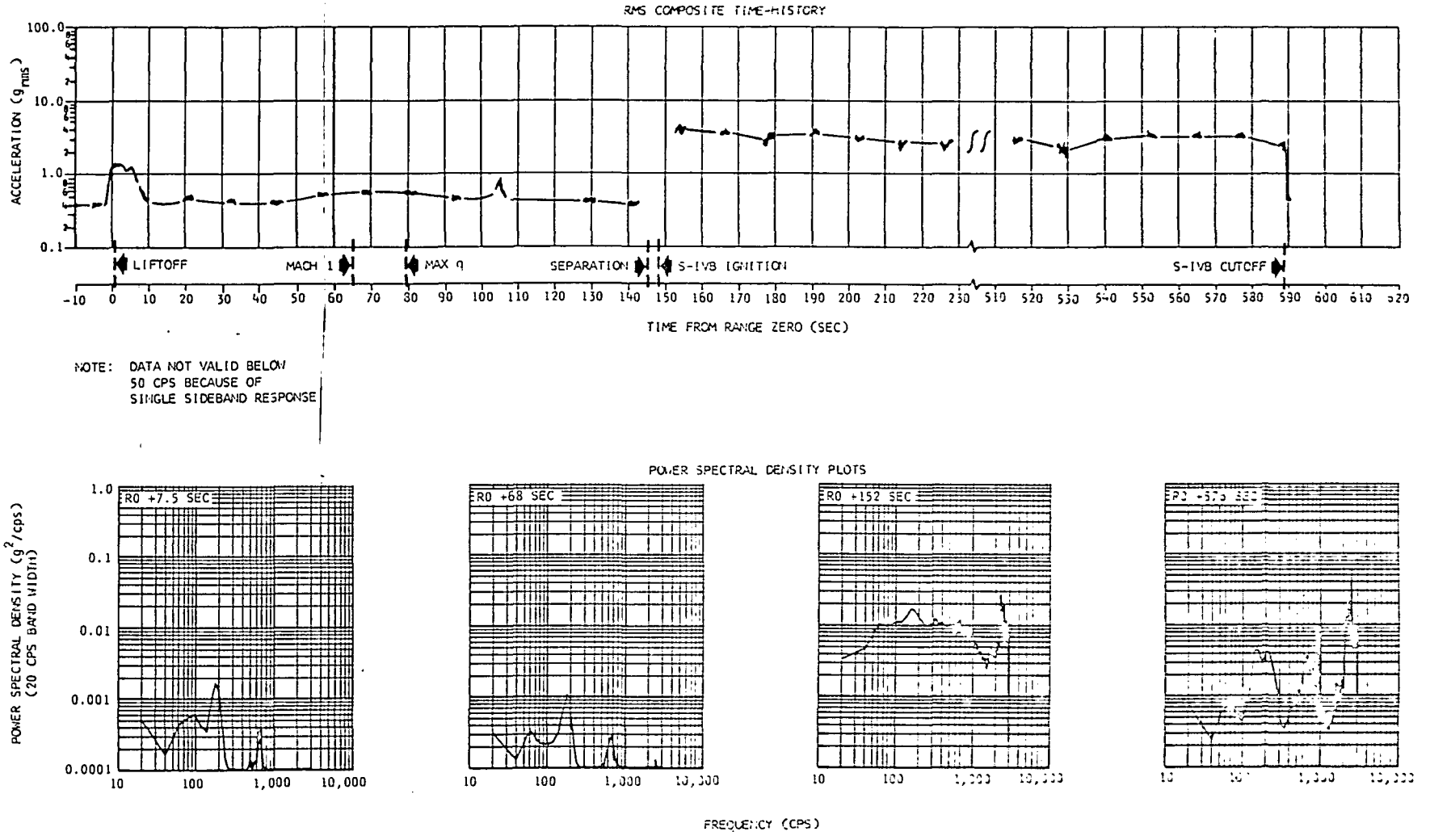

Figure 23-11. Vibration Measured on the Pitch Actuator Servo Valve, Tangential Direction (E0179-403)

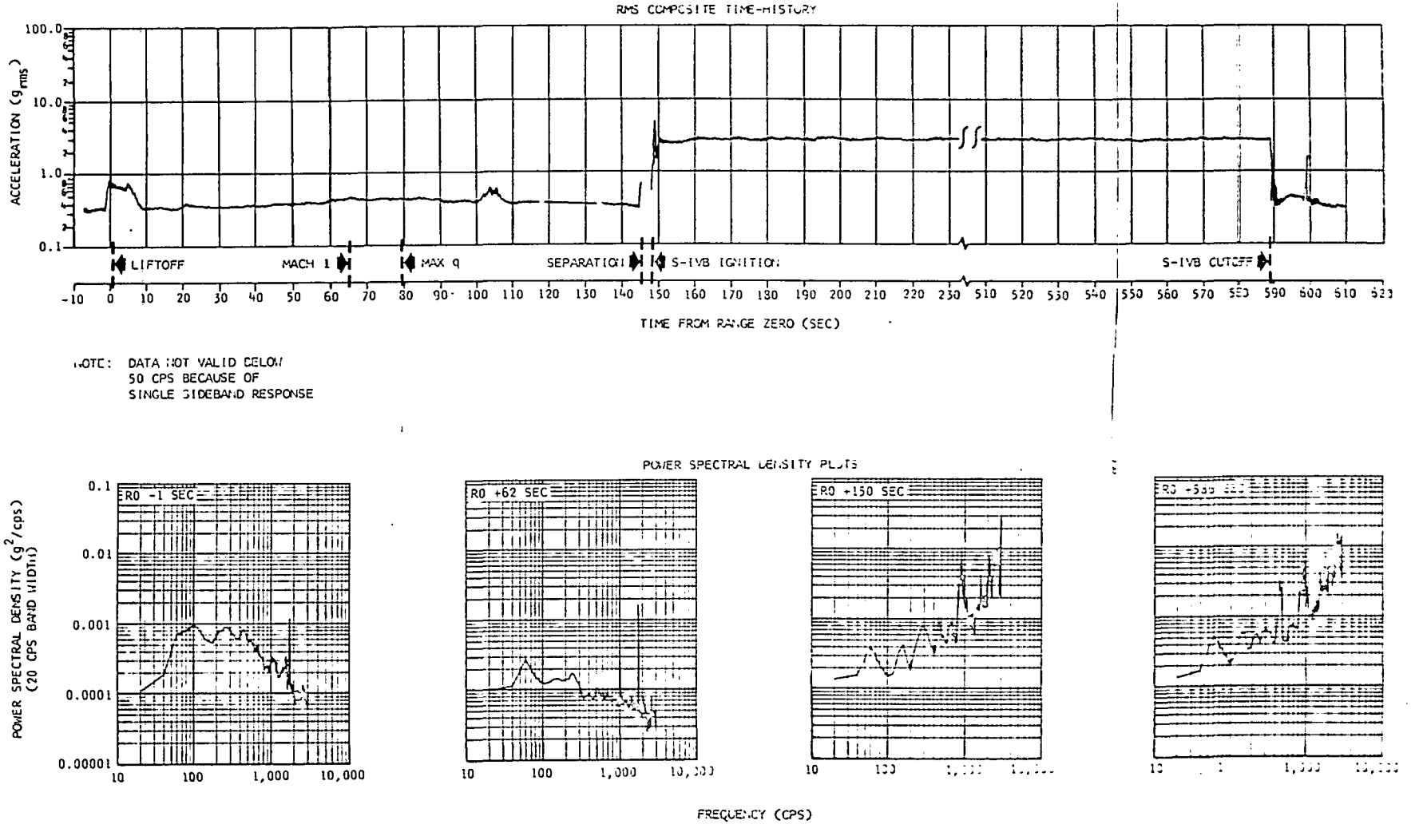

Figure 23-12. Vibration Measured on the Gimbal Block, Thrust Direction (EOC87-4C3)

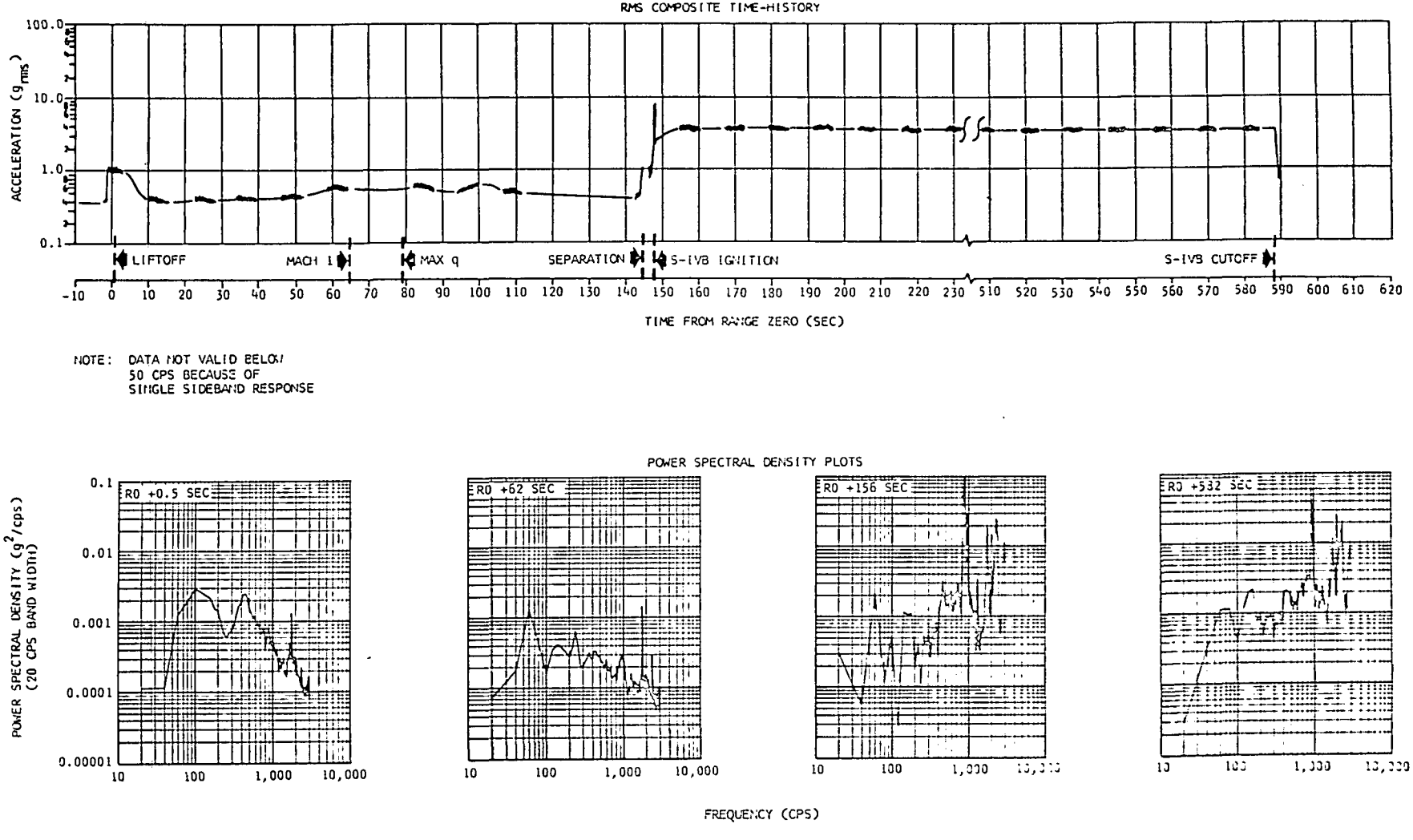

Figure 23-13. Vibration Measured on the Gimbal Block, Pitch Direction (E0088-403)

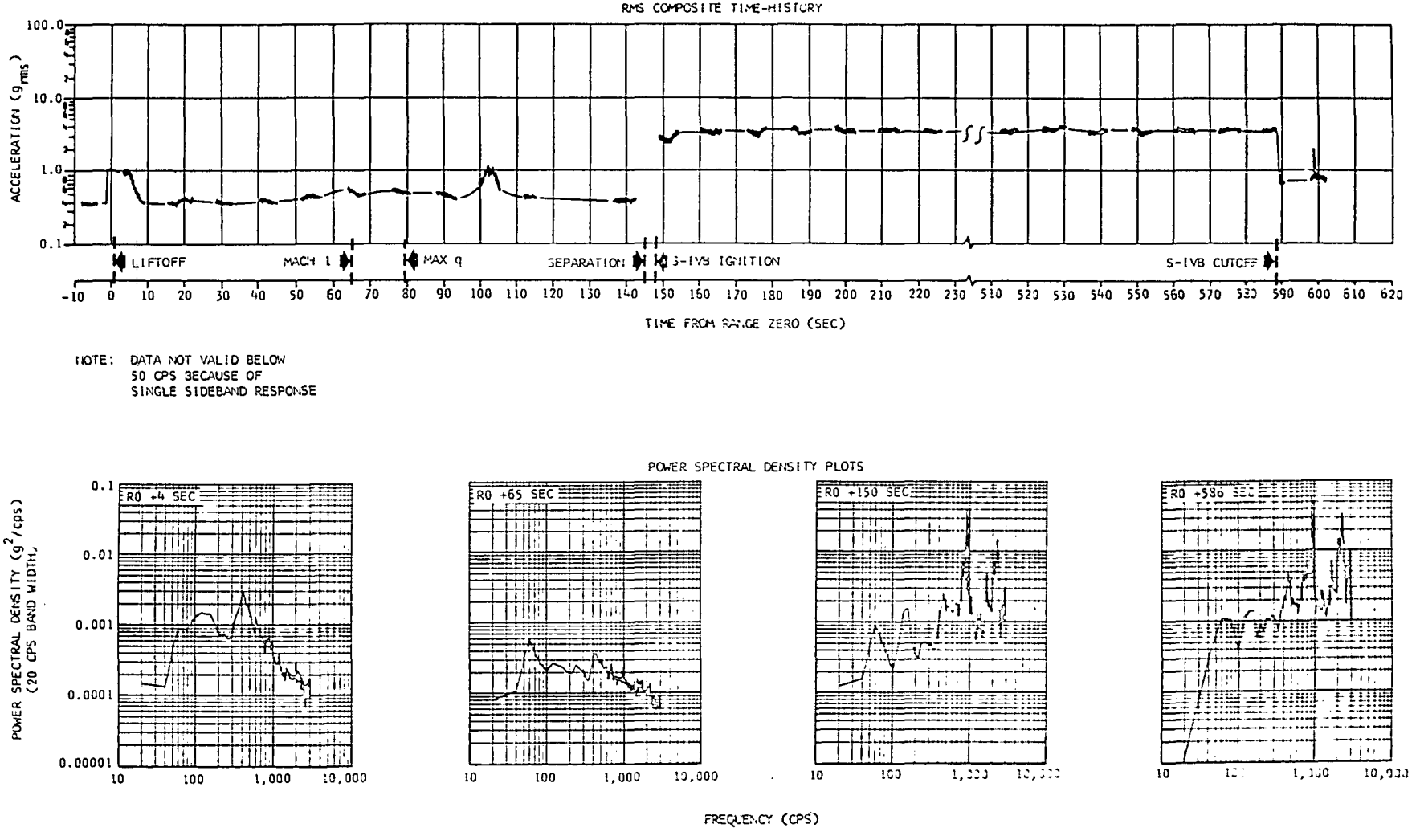

Figure 23-14. Vibration Measured on the Gimbal Block, Yaw Direction (E0089-403)

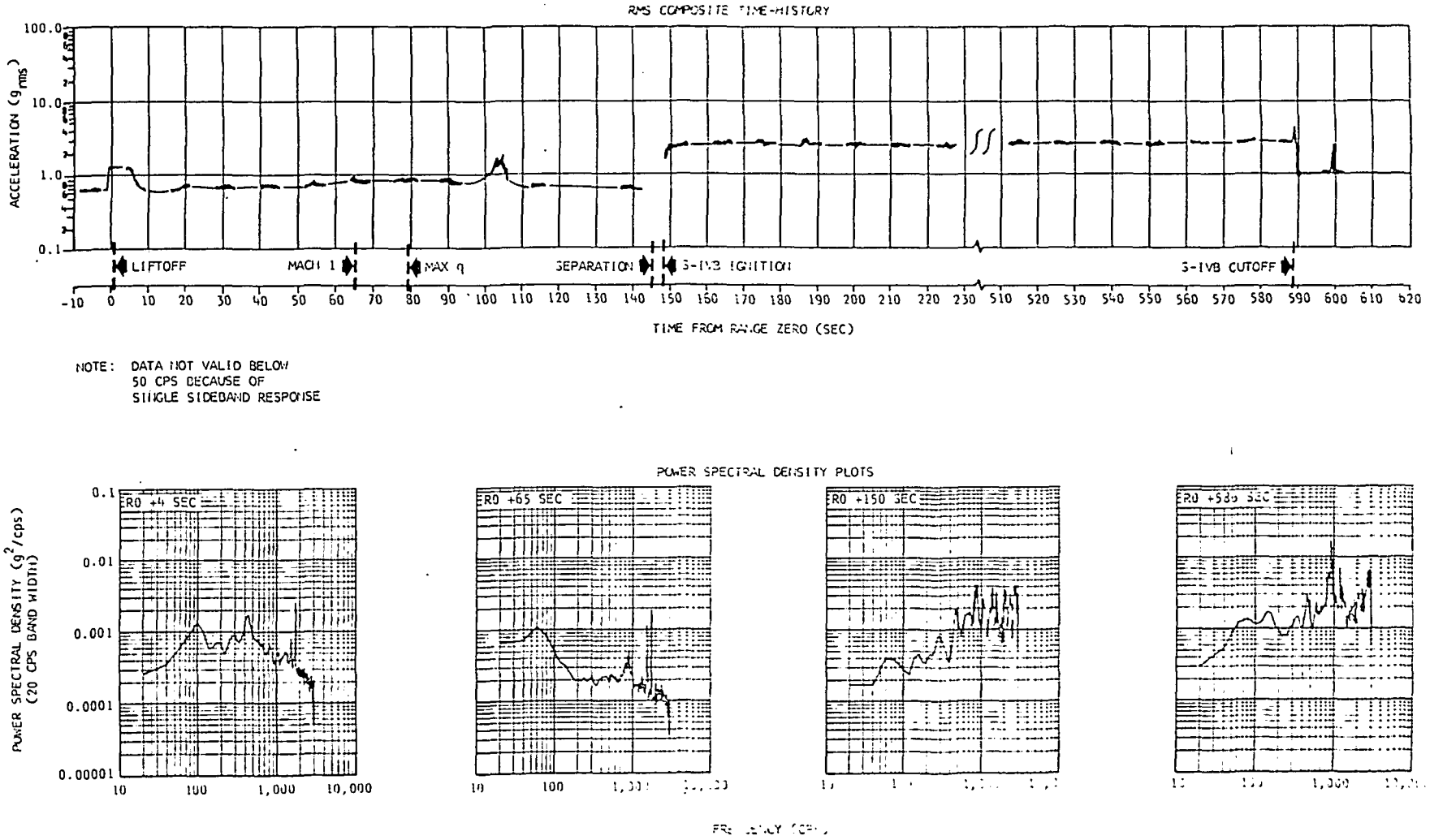

Figure 23-15. Vibration Measured on the Yaw Actuator Attach Point, Axial Direction (E0021-403)

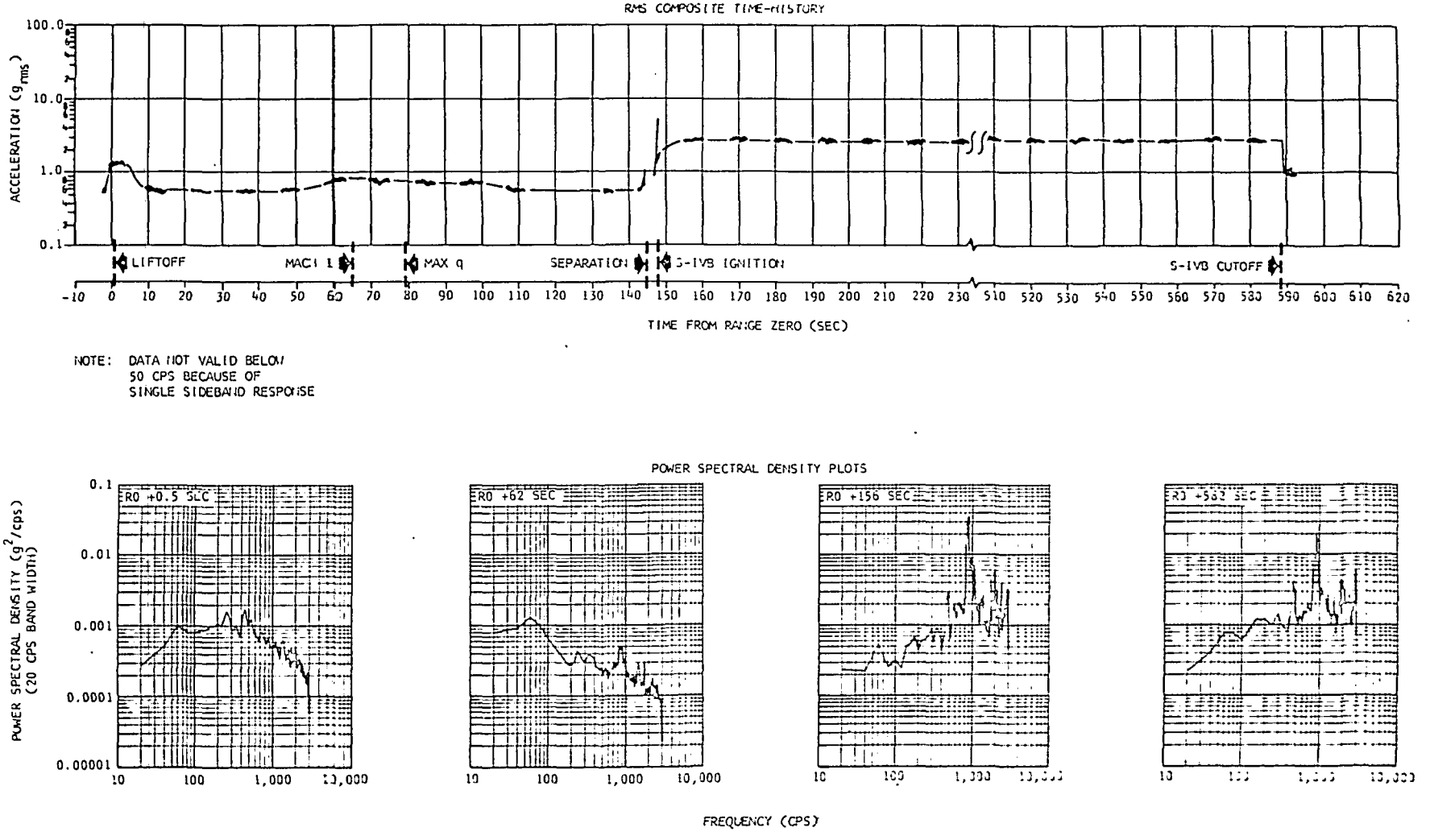

Figure 23-16. Vibration Measured on the Pitch Actuator Attach Point, Axial Direction (E0020-403)

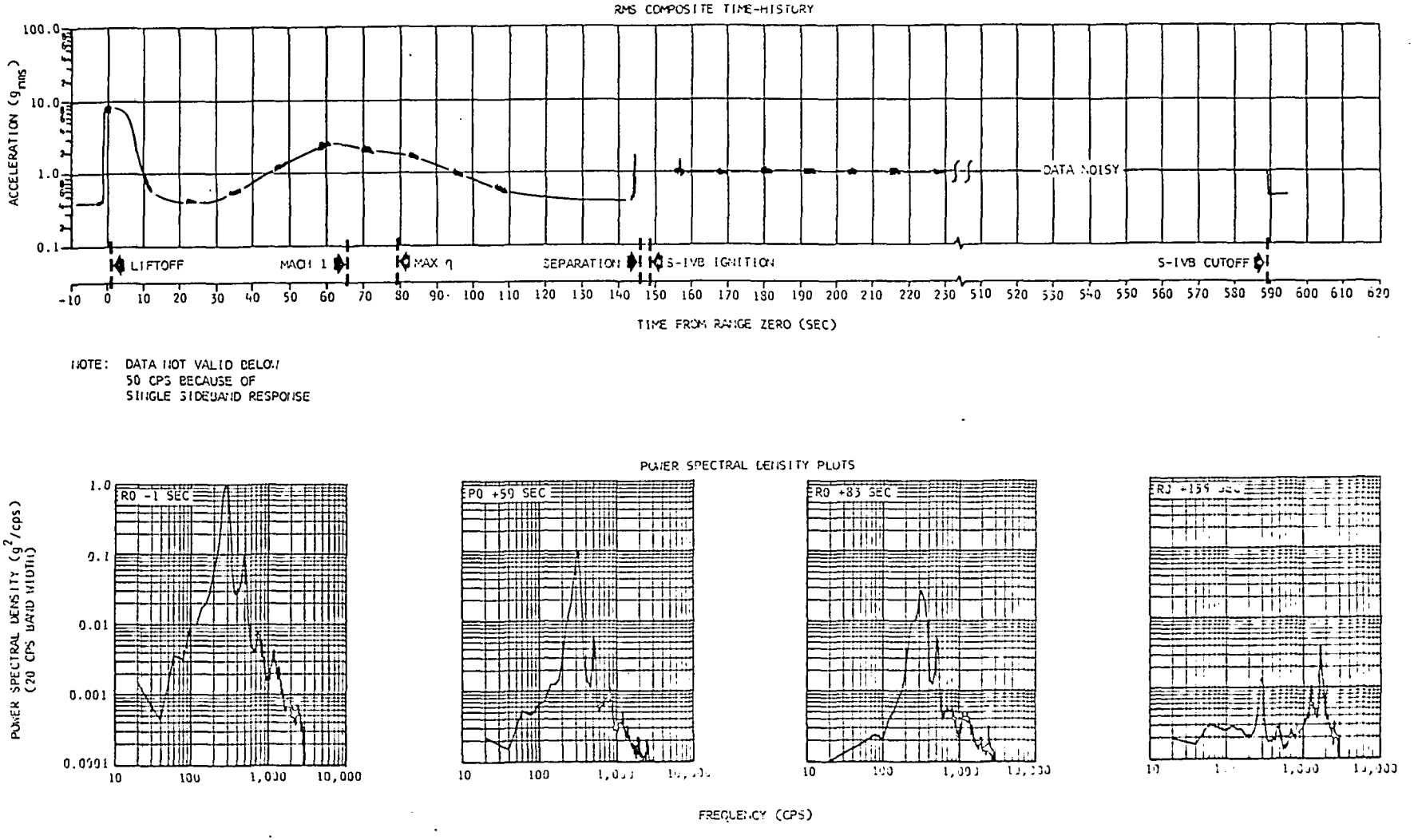

Figure 23-17. Vibration Measured at the Input to the Sequencer Panel, Thrust Direction (E0011-404)

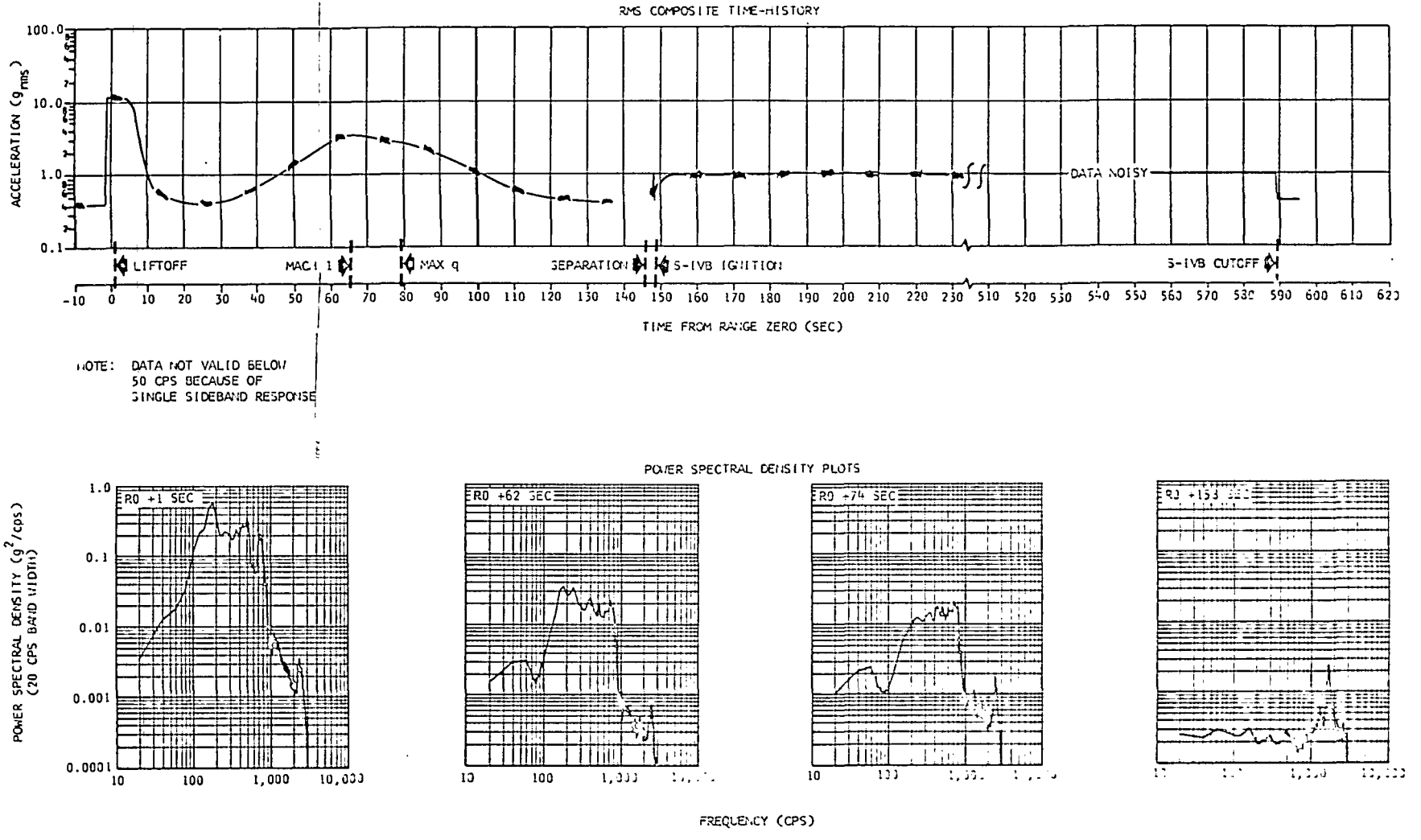

Figure 23-18. Vibration Measured at the Input to the Sequencer Panel, Radial Direction (E0012-404)

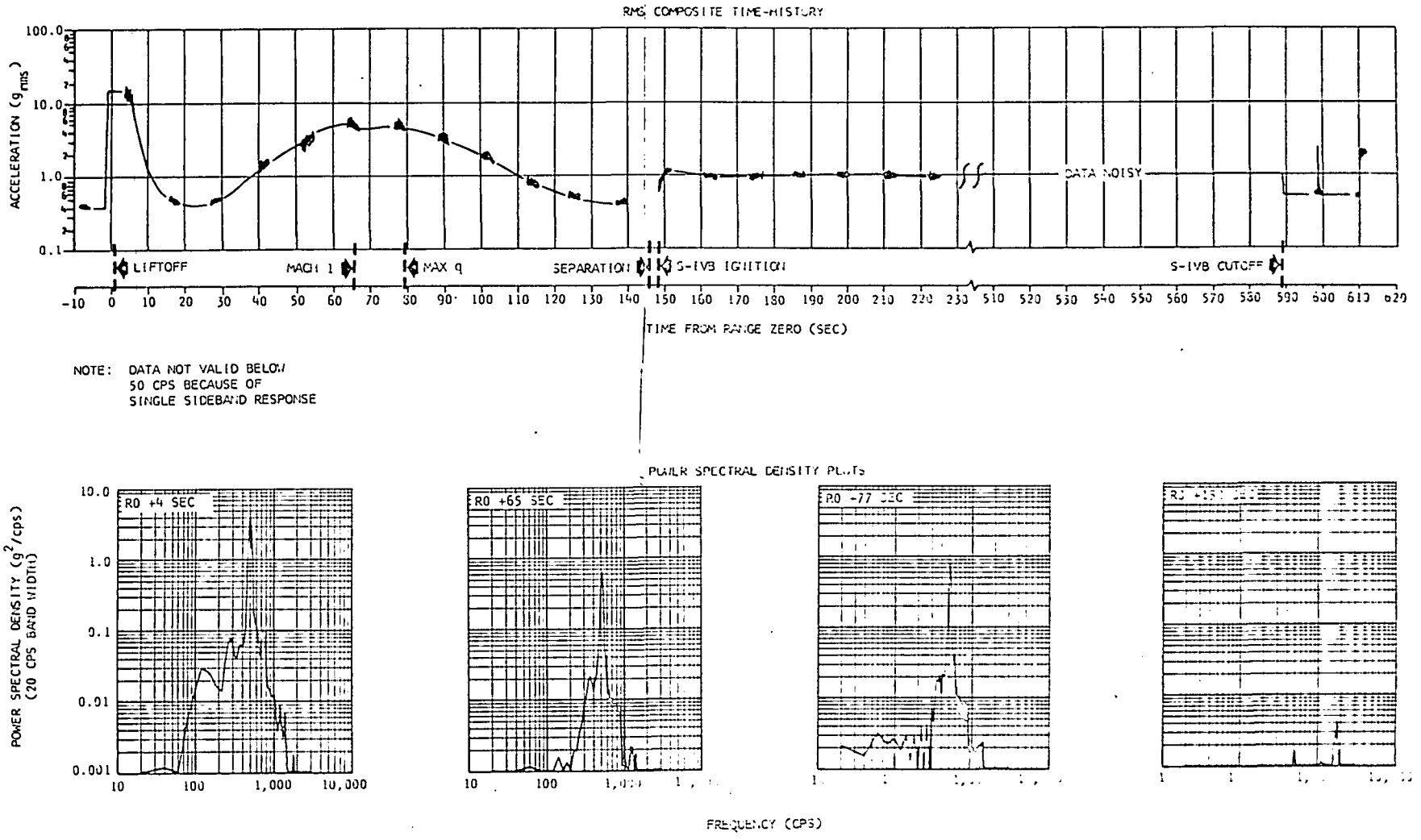

Figure 23-19. Vibration Measured at the Input to the Sequencer Panel, Tangential Direction (E0013-404)

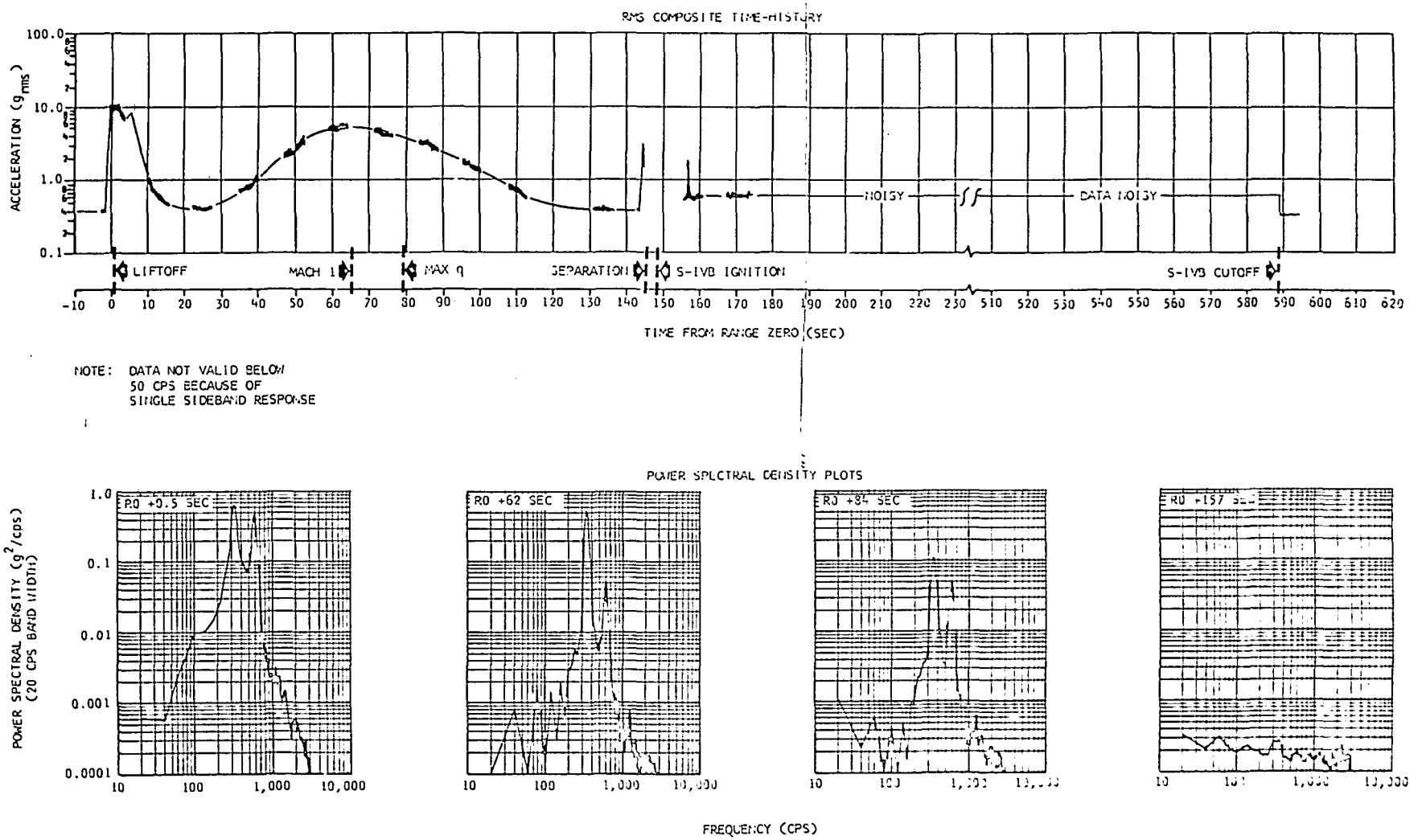

Figure 23-20. Vibration Measured at the Input to the Switch Selector Panel, Thrust Direction (E0014-404)

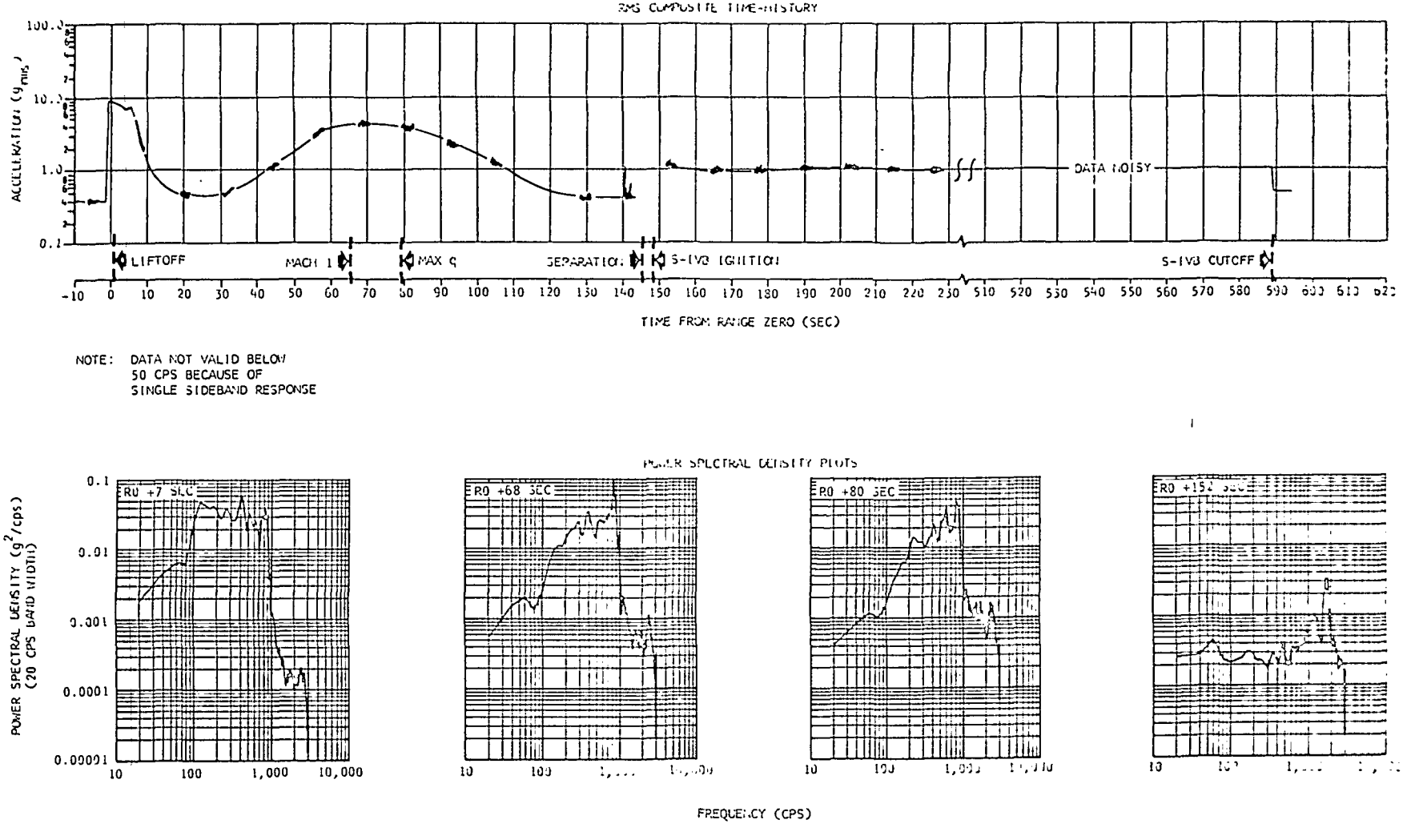

Figure 23-21. Vibration Measured at the Input to the Switch Selector Panel, Radial Direction (E0016-404)

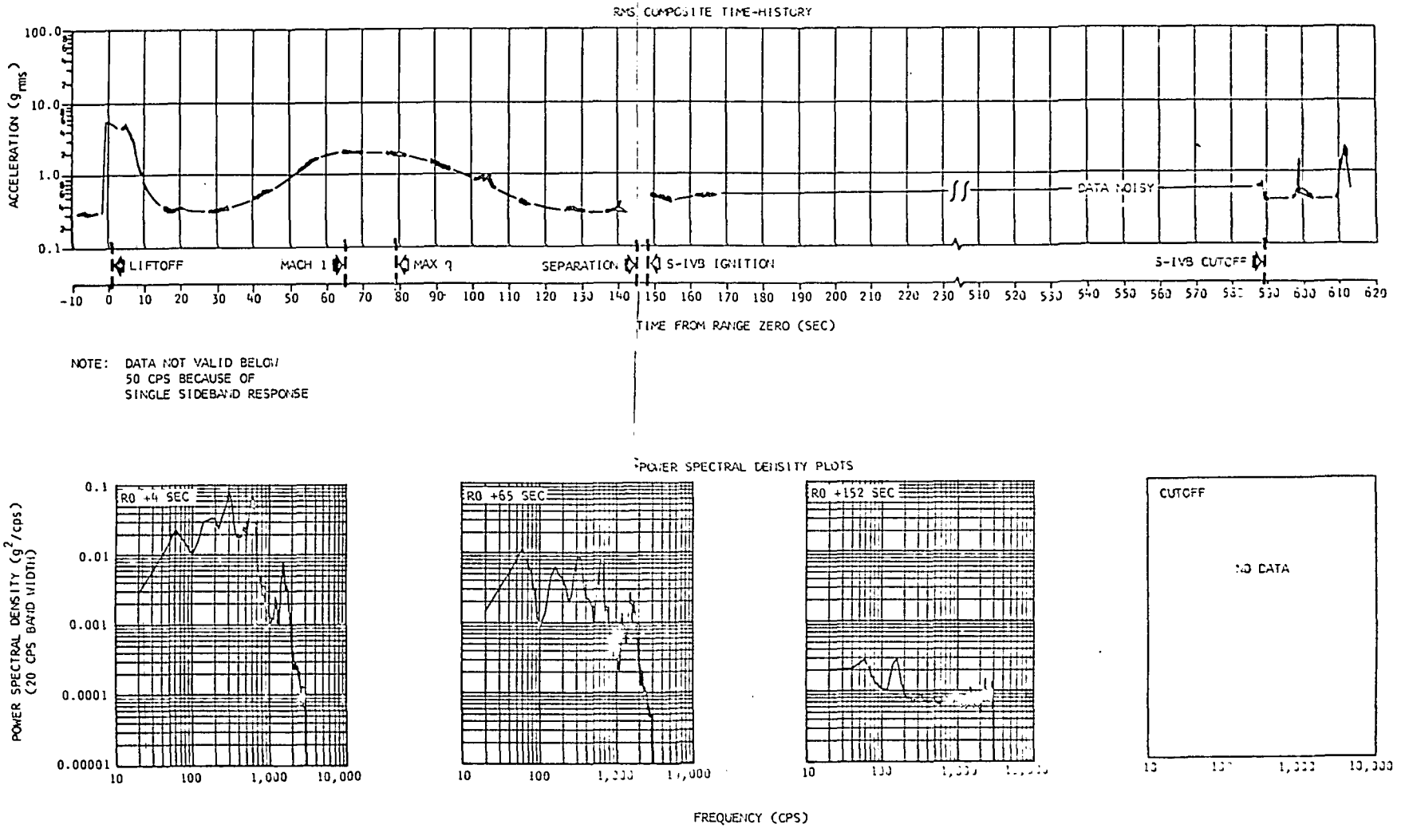

Figure 23-22. Vibration Measured at the Input to the Switch Selector Unit, Radial Direction (E0015-404)

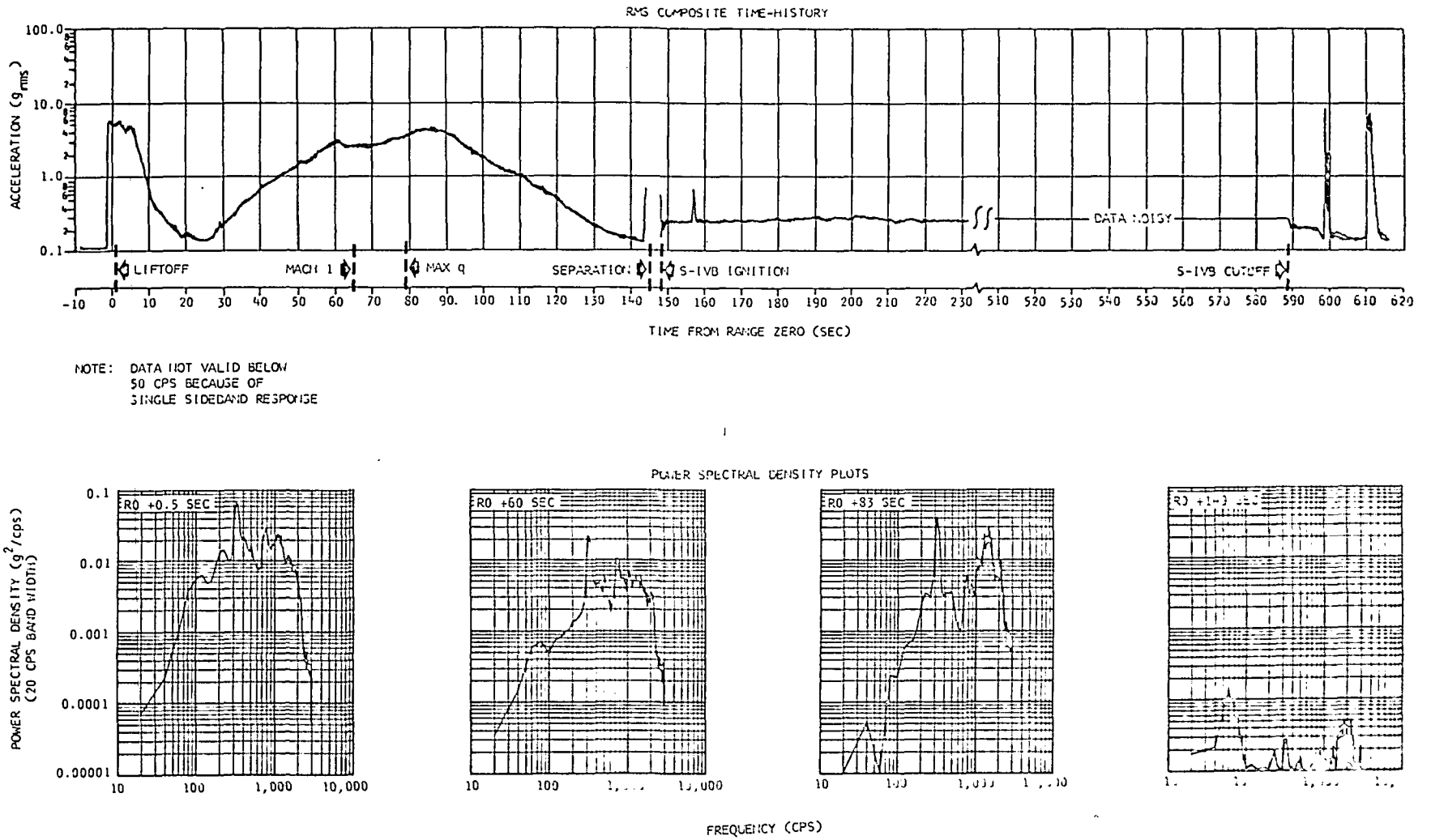

Figure 23-23. Vibration Measured at the Input to the PU Electronic Panel, Thrust Direction (E0005-411)

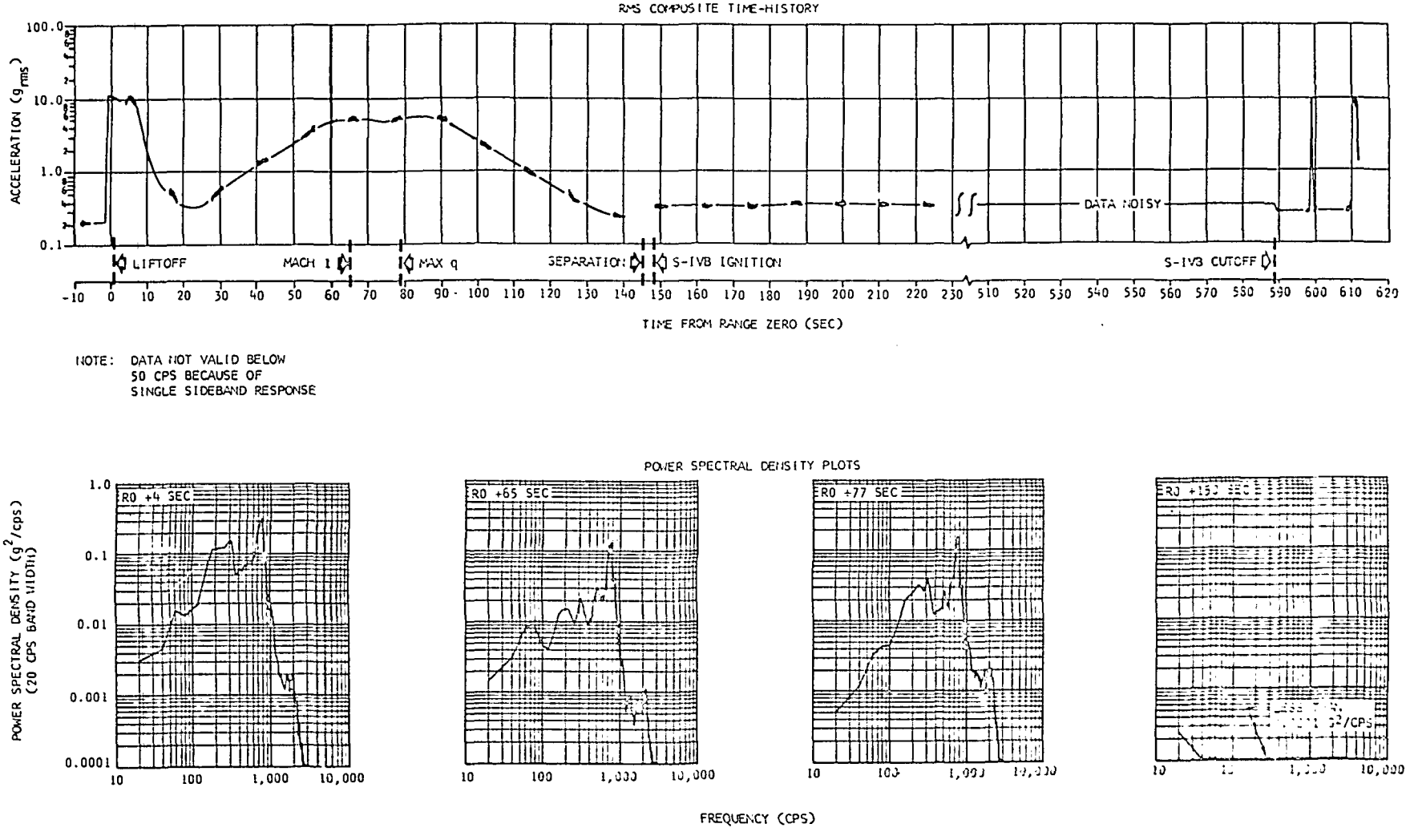

Figure 23-24. Vibration Measured at the Input to the PU Electronic Panel, Radial Direction (E0007-411)

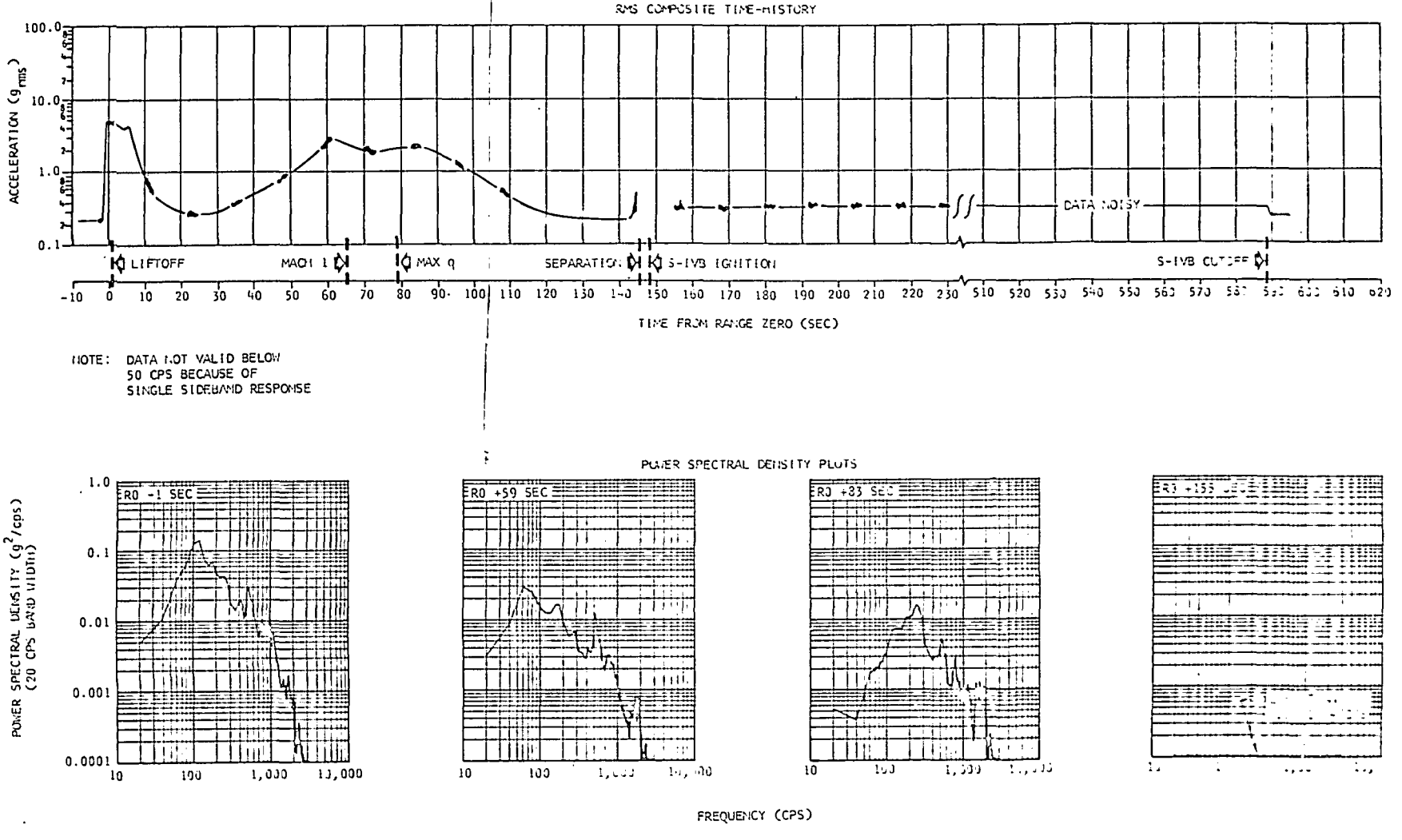

Figure 23-25. Vibration Measured at the PU Electronic Assembly, Radial Direction (E0006-411)

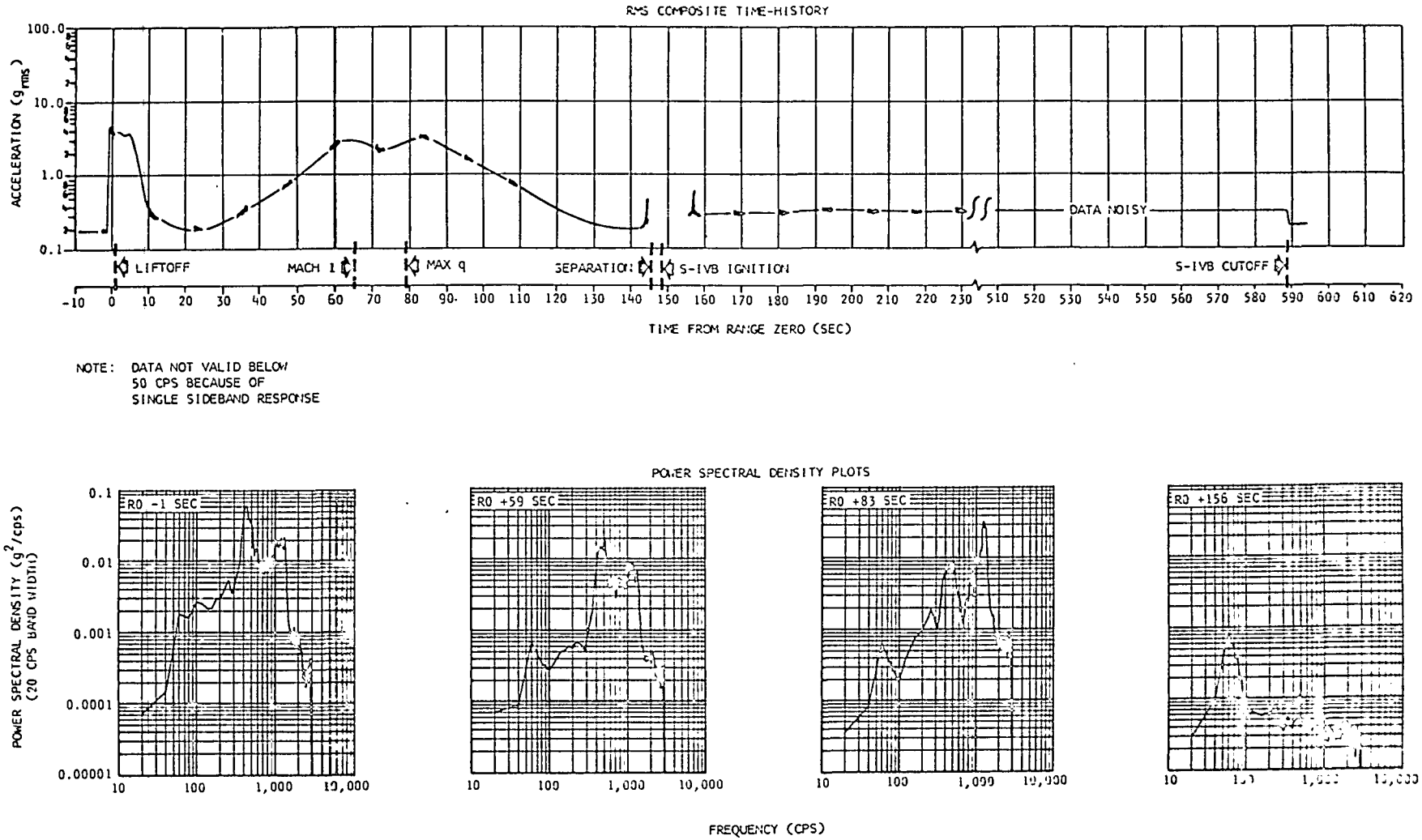

Figure 23-26. Vibration Measured at the Input to the Telemetry Rack, Thrust Direction (E0008-411)

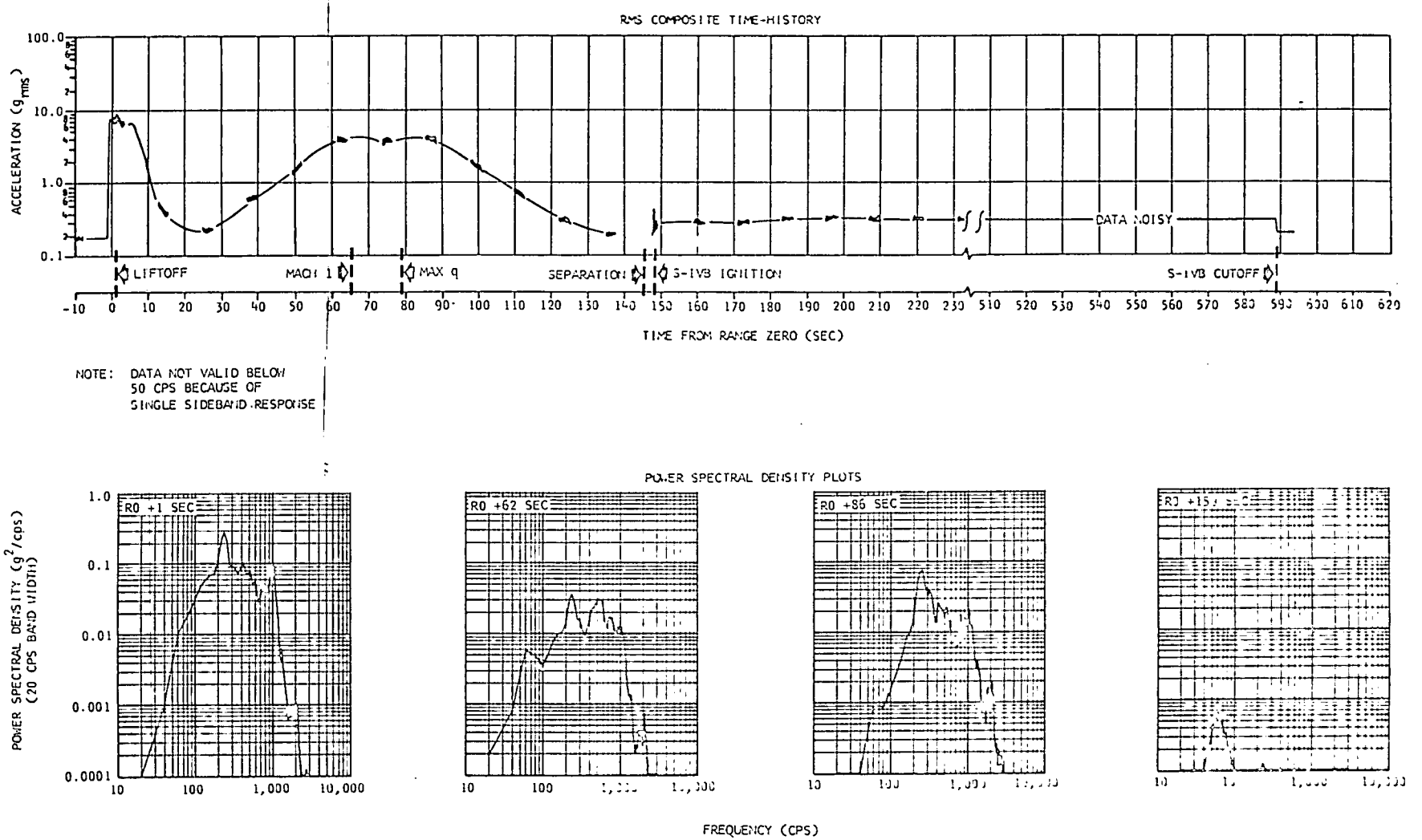

Figure 23-27. Vibration Measured at the Input to the Telemetry Rack, Radial Direction (E0009-411)

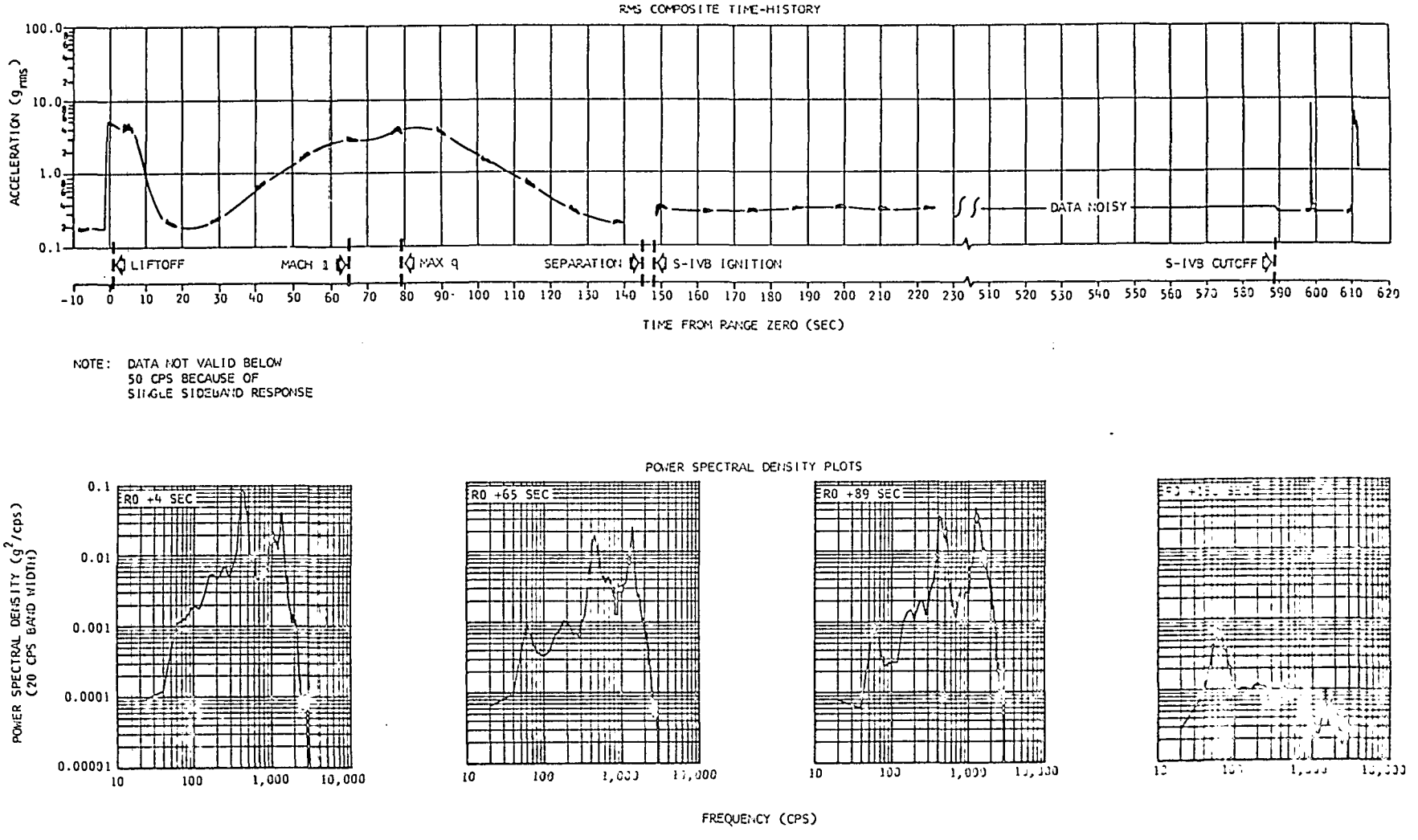

Figure 23-28. Vibration Measured at the Input to the Telemetry Rack, Tangential Direction (E0010-411)

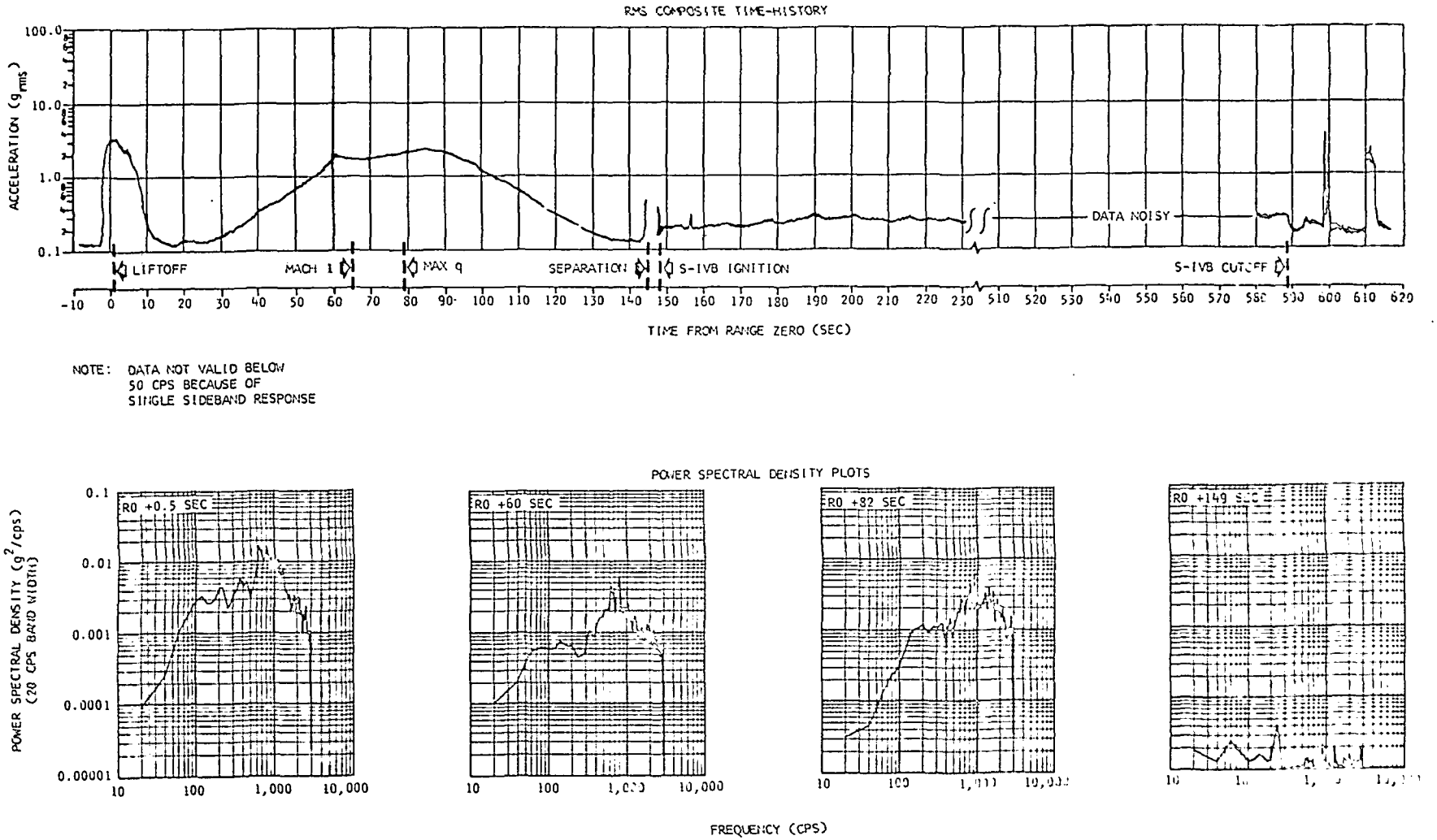

Figure 23-29. Vibration Measured on the Field Splice, Thrust Direction (E0017-411)

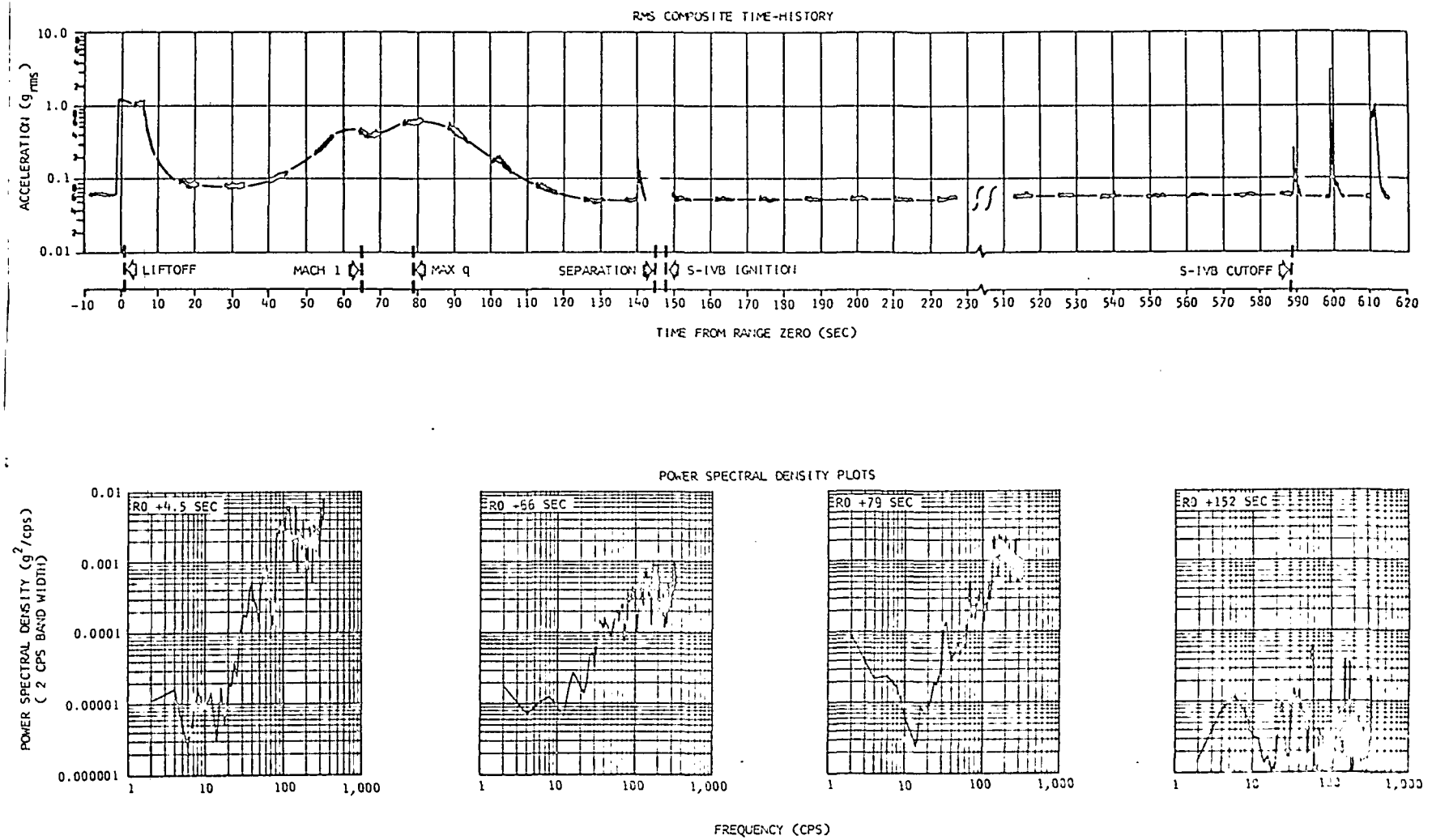

Figure 23-30. Low Frequency Vibration Measured on the Field Splice, Thrust Direction (E0085-411)

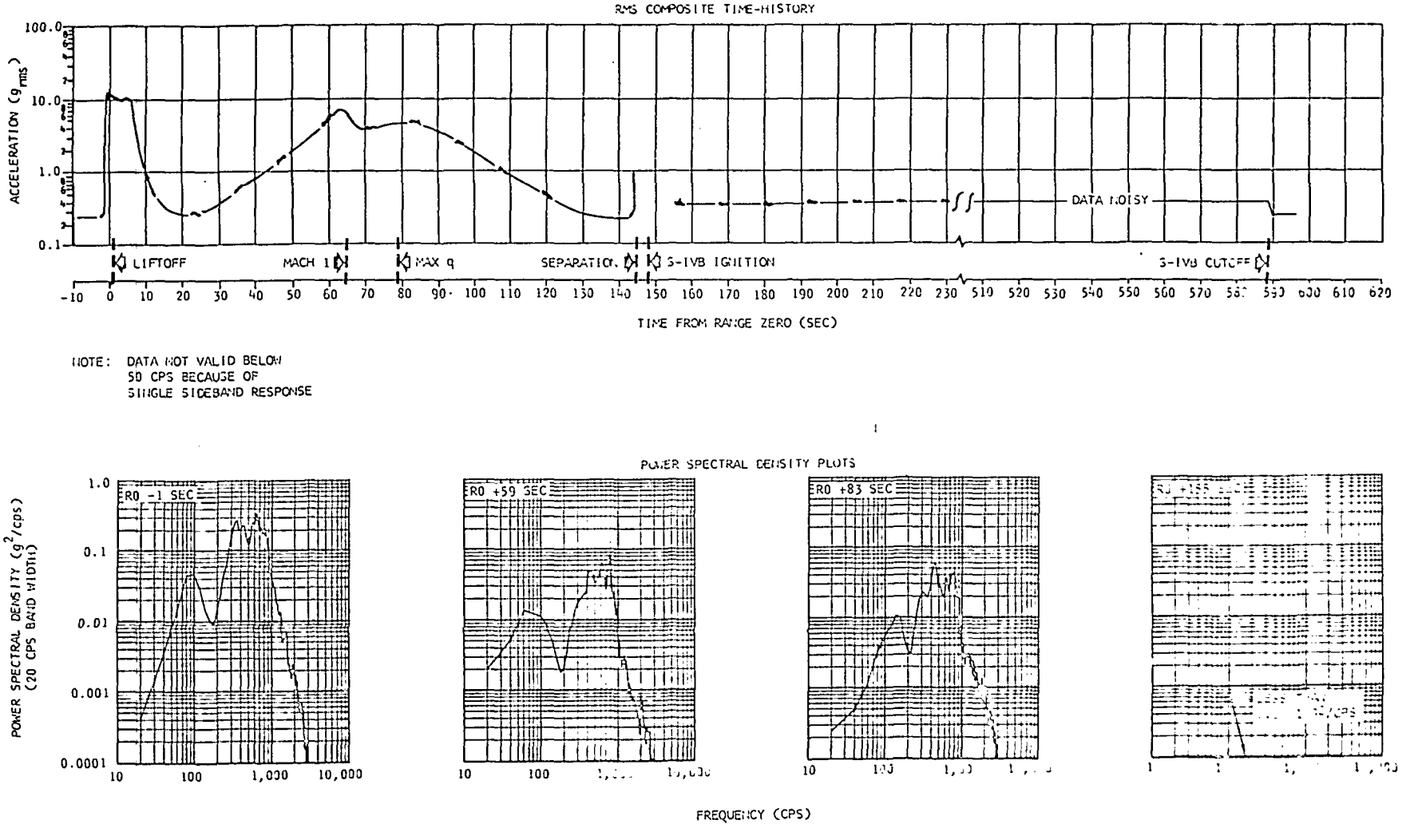

Figure 23-31. Vibration Measured on the Field Splice, Radial Direction (E0018-411)

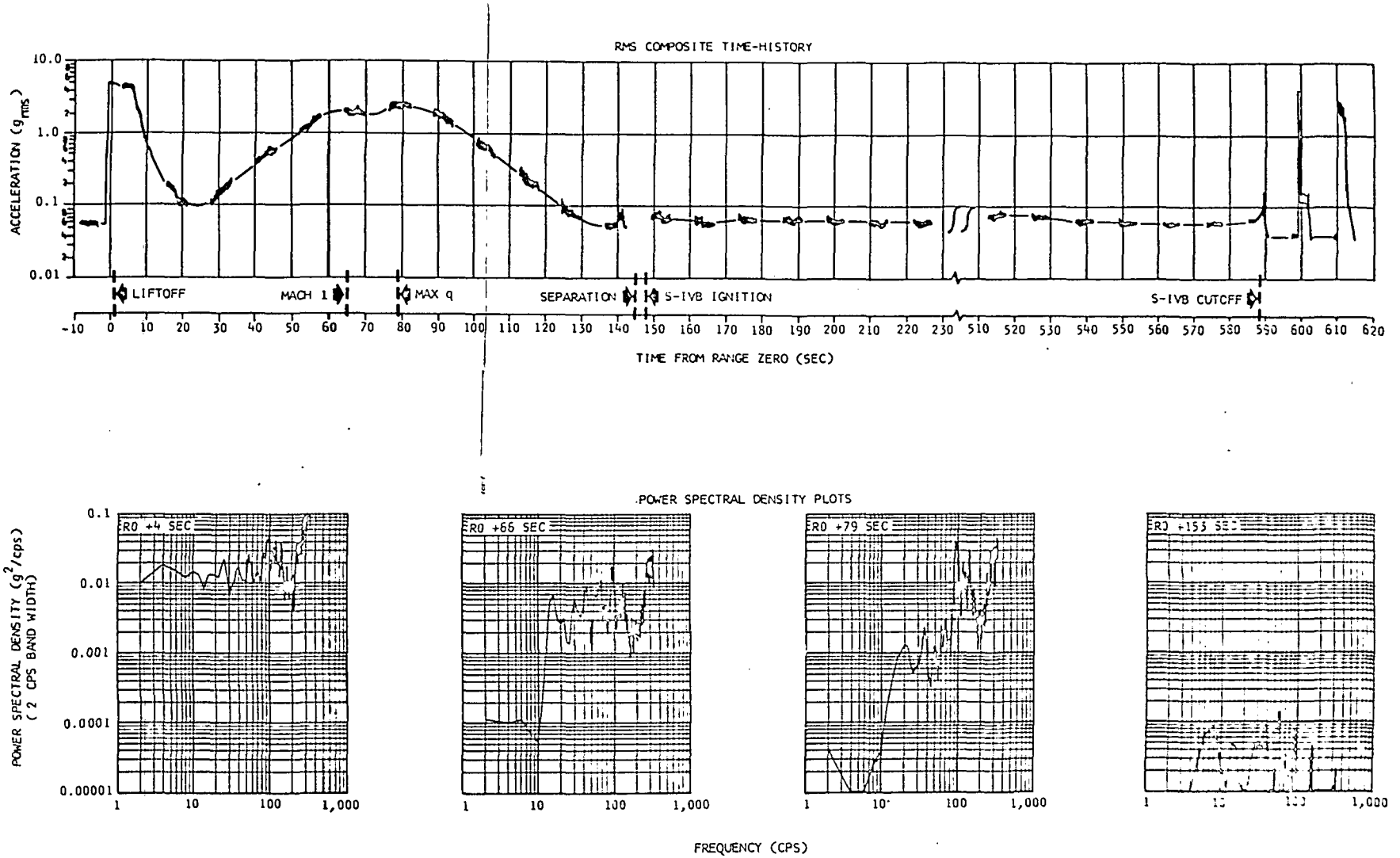

Figure 23-32. Low Frequency Vibration Measured on the Field Splice, Radial Direction (E0086-411)

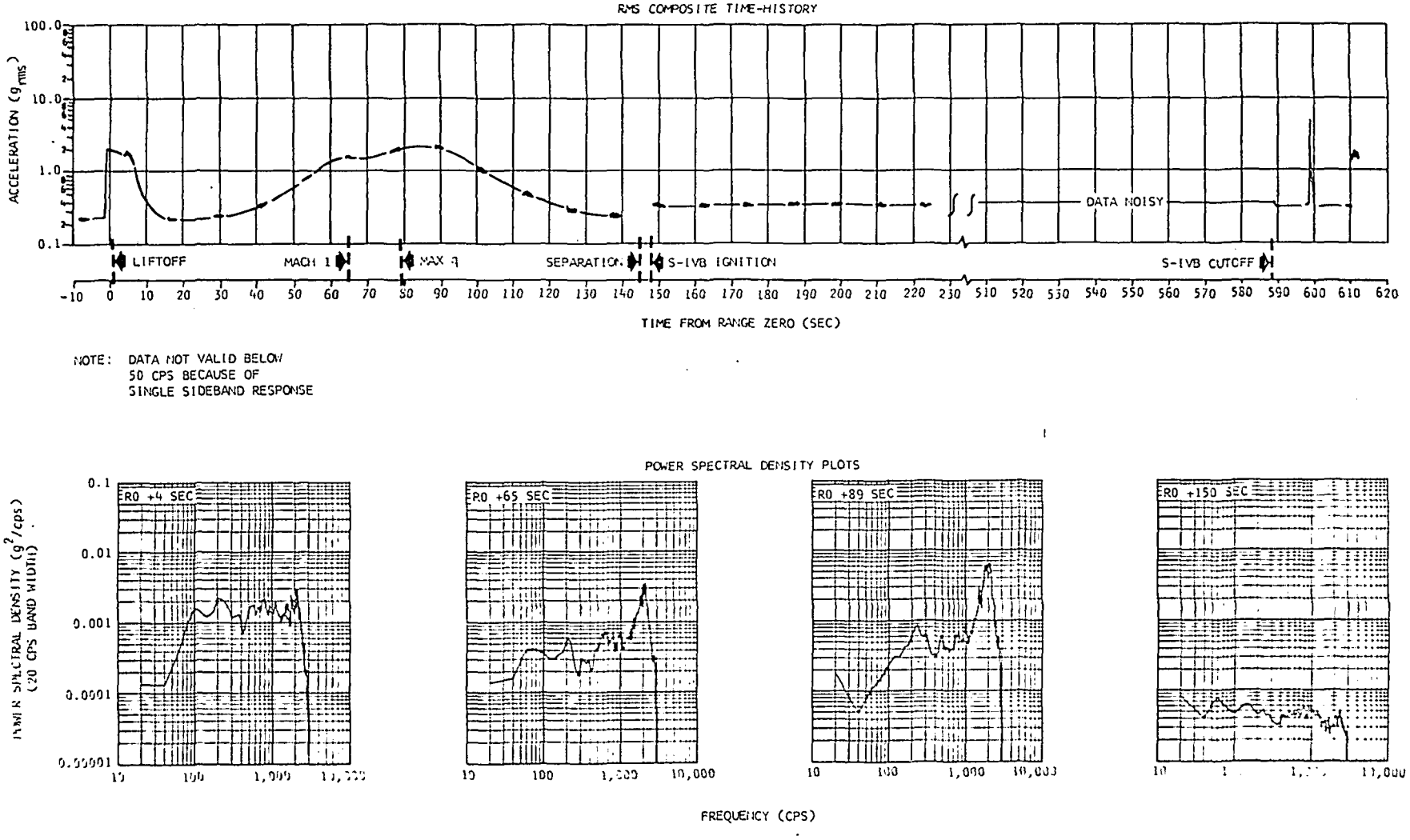

Figure 23-33. Vibration Measured on the Field Splice, Tangential Direction (E0019-411)

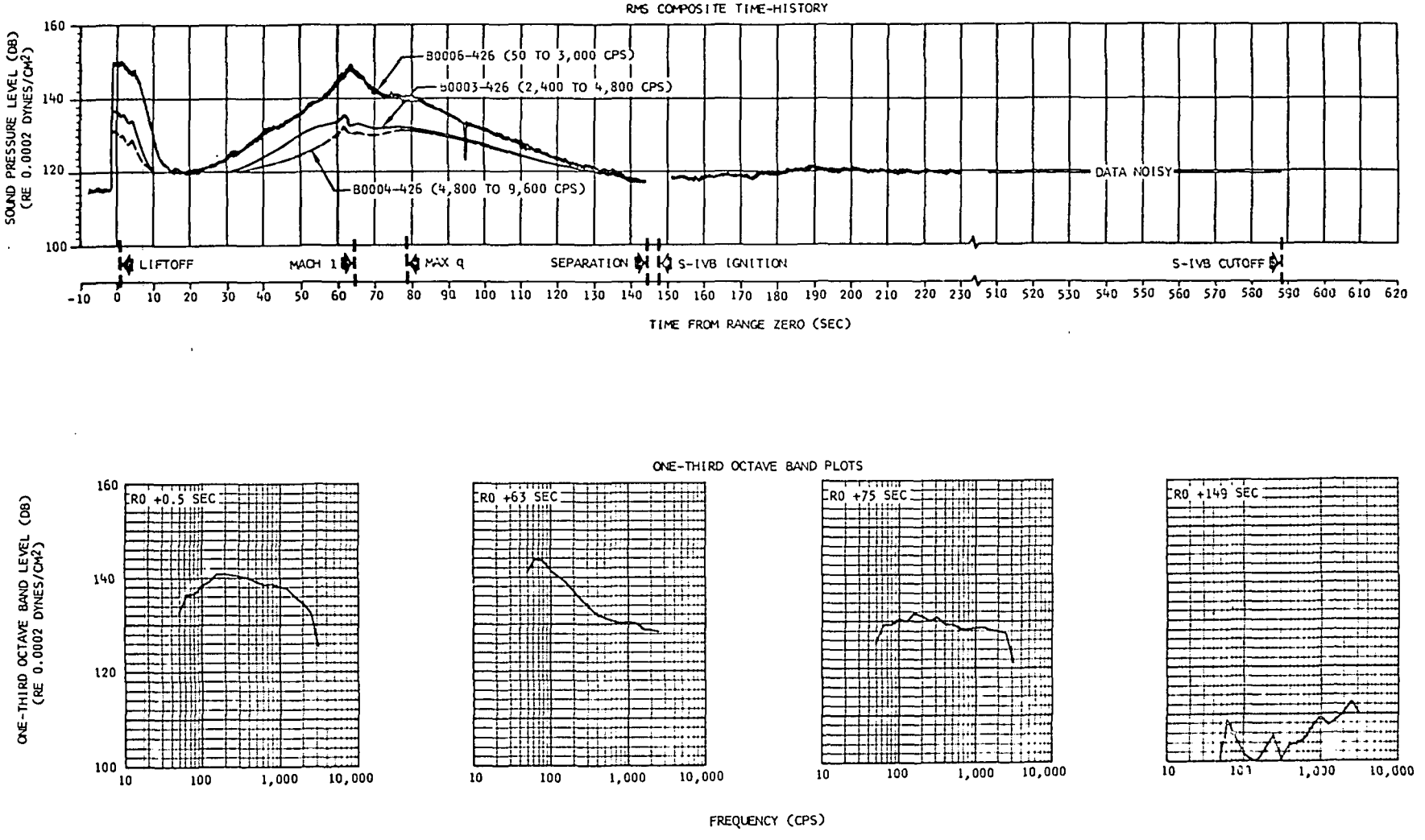

Figure 23-34. External Sound Pressure Levels Measured on the Forward Skirt

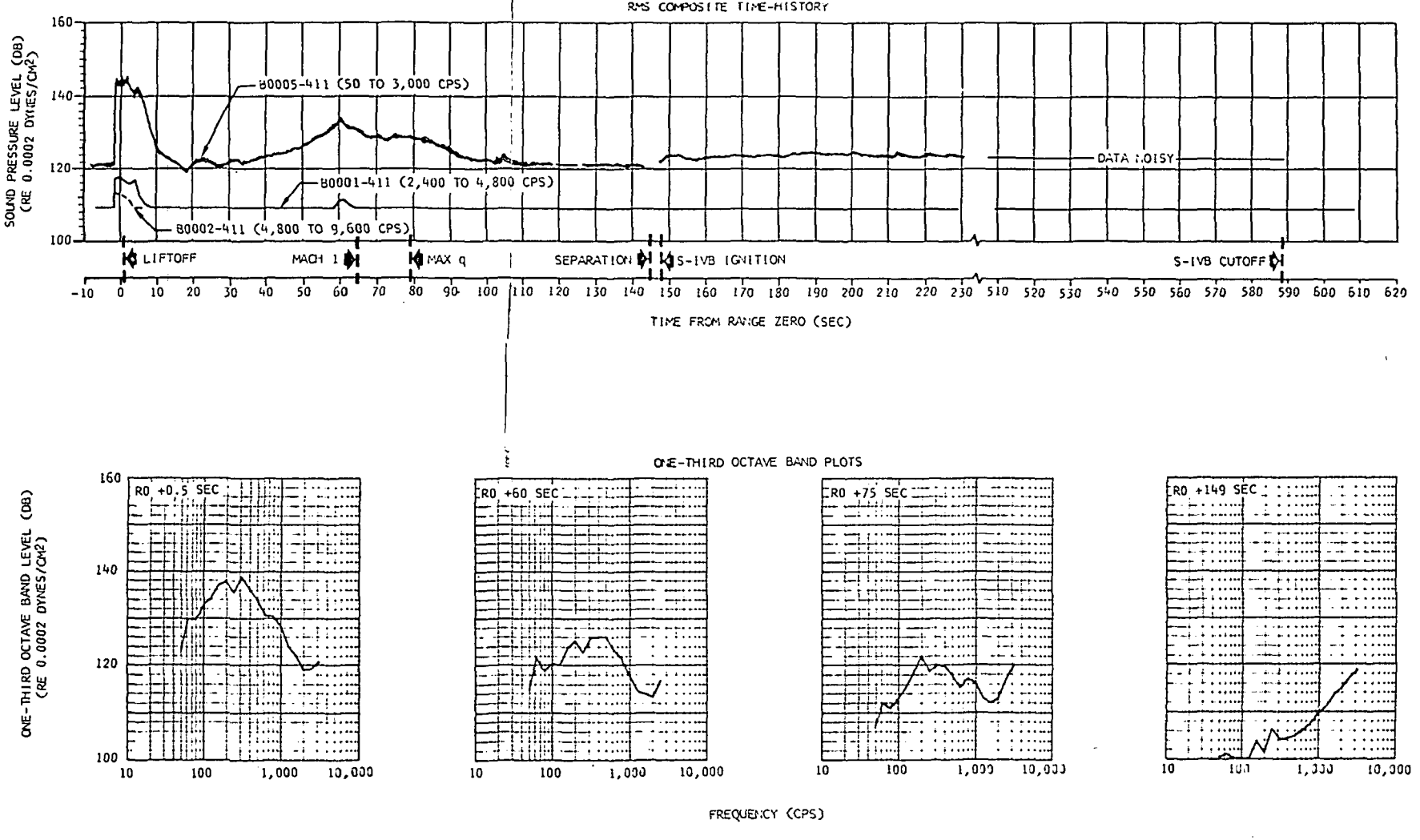

Figure 23-35. Internal Sound Pressure Levels Measured in the Forward Skirt

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24. AERO/THERMODYNAMIC ENVIRONMENT

This section presents the aerodynamic and thermodynamic data pertaining to the S-IVB stage during the AS-202 flight. Included are structural temperatures, heat flux due to retrorocket impingement, propellant heating, internal component temperatures and pressure differentials. Figure 24-1 presents the locations of pressure and temperature measurements made for this analysis. In general, the objectives of the measurements were met and the data obtained were within design operating limits of the stage.

24.1 Thermodynamic Environment

24.1.1 Structural Heating

All measured structural temperatures were within the design limits of the stage. In all, there were 41 temperature sensors: ten were located on the forward skirt, nine on the LH2 tank, twenty on the aft skirt, and two on the aft interstage as shown in figure 24-1. All sensors performed satisfactorily during AS-202 powered flight. The measurements obtained will be discussed individually. The temperature histories were of the same shape as on the AS-201 and AS-203 flights, with maximum temperatures falling between those of AS-201 and AS-203, as would be expected from the particular trajectory flown. Maximum heating occurred at about the same time as AS-201, and 10 sec later than AS-203.

Simulations differed from AS-201 in the following two ways: (1) wind tunnel pressure data were used instead of zero pressure coefficients on the forward skirt, (2) a transition Reynolds number based on $\frac{Tw}{Twa} = 0.5$ was used instead of the AS-201 transition Reynolds number of 5×10^5. This transition occurred between RO +100 and RO +120 sec, depending on the vehicle location.

The flight data presented were obtained from digital plots (PCM). Most of the simulations agreed well with the actual peak temperatures, although there were some large (50 deg R) discrepancies. Simulation of subsonic heat transfer was not as successful, since predictions fail to show the temperature drop experienced by most sensors during approximately the first 60 sec of flight.

24.1.1.1 Forward Skirt

Figure 24-2 shows the measured and postflight simulated skin temperatures at the forward end of the forward skirt (DAC sta 671). Sensors C0081, C0082, C0083, and C0084 show the circumferential temperature distribution on the skin. All of these measurements were in close agreement at lift-off. Three of them remained in close agreement, and had a temperature-time history of the same general shape as AS-201 and AS-203. The fourth measurement, C0082, lagged significantly, as it did on AS-201, with no apparent justification. (This measurement was not included on flight AS-203.) A review of the stage structural design and operation revealed no differences from the other three sensor locations, such as structural heat sinks, system coolants or vented gases. Again, as on AS-201, the effect of the intercostal on sensors C0081, C0082, and C0083 appears to be negligible and since the angle-of-attack was small during heating, no circumferential distribution of heating was apparent.

Comparisons between skin and stringer temperatures at DAC sta 671 and 600 are shown in figures 24-2 and -3, respectively. In both cases, maximum skin temperatures exceeded stringer temperatures, as was expected. Stringer temperature sensor C0110, however, showed considerably less response to aerodynamic heating than the skin sensor next to it, C0109. As shown from the postflight simulations, this would not be expected. The same large temperature difference between these two sensors occurred on AS-201 and no explanation has been found. An investigation has revealed no structural dissimilarities between the two sensor locations.

Figure 24-3 shows the data and simulations of temperature sensors C0239, C0111, and C0240 in the same radial location and moving aft on the forward skirt with C0240 closest to the tank. Since the internal structure was significantly different at each of the sensor locations, the measurements cannot be related to one another. The simulations follow the measured temperatures reasonably well for C0239 and C0111, although measured temperatures lagged behind the simulations. Sensor C0240 was located very near the skirt-tank junction, and the simulation produced rapid cooling from heat flow to the tank. This conduction path was evidently not as good as expected, since measured data did not verify the sharp temperature tail off-predicted at RO +110 sec.

24.1.1.2 LH2 Tank

LH2 tank temperatures at liftoff ranged from 455 deg R to 510 deg R (figure 24-4). The lower temperatures indicate the presence of frost over the sensor and/or shading from the solar input. All tank skin temperature measurements increased about 40 deg R during boost, with the exception of C0107, which increased 65 deg R. There is no apparent explanation for this, since sensors at the same station number (i.e., C0088) or at the same radial location (i.e., C0076) with the same liftoff temperature as C0107, did not show a similar behavior.

Only one postflight simulation of tank temperature sensors was made, since all sensors could be adequately represented by the same computer model, and the effect of varying running lengths was previously found to be negligible. The simulated temperature rise was 40 deg R, the same as measured by the sensors, but the shape of the curve did not follow the measured data. The simulation predicted that the maximum temperatures would occur earlier than the measured data indicated.

24.1.1.3 Aft Skirt

Aft skirt temperatures were difficult to simulate successfully in the subsonic flight regime. Twelve of the aft skirt sensors were covered with black paint. The analysis, being conservative, assumed direct solar radiation to these sensors. This was not the case, since no sensor was always perpendicular to the sun. Actually, some of these sensors were in the shade part of the time. The simulations for sensors covered with black paint are, therefore, always too hot. Aft skirt skin temperatures are presented in figure 24-5.

Simulations for temperature sensors C0045, C0113, C0114, and C0115 were reasonably close to the measured data in the supersonic regime. The stringer sensors, C0113 and C0115, showed lower temperatures than the skin sensors at the same DAC station, as did the simulations. The maximum measured temperature difference between skin and stringer sensors C0045 and C0113, was 45 deg R and the maximum difference between C0114 and C0115 was 40 deg R. The predicted difference in both cases was 35 deg R.

Temperature sensors C0045 through C0048 measured the circumferential temperature distribution at DAC sta 211. The simulation agreed within 10 deg of the actual measured temperatures in the supersonic regime, and the shape of the curves for measured data and simulation are similar. Three different simulations were required to account for differences in internal structure under sensors. Sensors C0116 and C0117 were different only in their radial locations on the aft skirt. Their temperature histories should therefore be identical, and in fact, they are nearly so.

The simulation of the aft skirt temperatures in the subsonic regime is poor. The effect of the subsonic portion of the flight on the maximum temperatures is small as indicated in figure 24-5 (page 2 of 3) where a simulation starting at the temperature corresponding to RO +60 sec is shown for comparison.

Temperature simulation for the sensors located on both sides of the auxiliary propulsion system (APS) modules were about 25 deg R too high for sensors C0178, C0180, C0182, and C0184, and were 10 deg R too high for sensors C0179, C0181, C0183, and C0185 at the maximum temperature before separation. Protuberance induced heating was not considered (i.e., $h/h_o = 1.0$). As mentioned previously, variations from the assumed solar input, due to shadows from the APS modules or the vehicle orientation, may explain these discrepancies. Temperature sensors C0221, C0222, and C0223 near the front of APS module 1, had approximately the same measured maximum temperature, but C0223 lagged about 10 sec behind the other two in reaching this maximum.

24.1.1.4 Aft Interstage

Aft interstage temperatures (figure 24-6) were measured during flight by two sensors located on the skin midway between stringers. Both sensors were covered with Korotherm TC-320, used to protect the interstage from retrorocket plume impingement as on AS-201. Sensor C0118 is covered with 0.010 in. Korotherm, and C0122 with 0.030 in. Korotherm, which explains the lower heating rate sensed by C0122. The allowable variation of the Korotherm thickness could account for the difference in maximum temperature between the measurements and simulation for sensor C0118.

24.1.1.5 Protuberances

Three protuberances were instrumented to record temperature data during the S-IVB-202 flight (figure 24-7): the LH2 feed line fairing (C0091), the APS fairing (C0128 and C0129) and the main tunnel (C0049, C0227, C0241, C0242 and C0243). The protuberances were uninsulated except for the forward 6 in. of the main tunnel centerbody which was covered with approximately 0.060 in. Korotherm (as a result of this part being interchanged between -201 and -202). None of the temperature sensors were covered with Korotherm.

The temperature simulations on the protuberances were obtained by assuming the flow approaching a given protuberance passed through an attached two or three dimensional shock (depending on the surface geometry) and expanded to the pressure coefficient at the point in question. Boundary layer immersion of the sensor locations was considered by assuming a 1/7 power velocity and temperature distribution.

24.1.1.5.1 LH2 Feedline Fairing

The data show a fairly constant surface temperature until approximately RO +70 sec when aerodynamic heating begins. The calculated temperature rise rate agrees reasonably well with the data up to RO +140 sec. The recorded data show a break in the temperature rise rate at RO +140 sec indicating the transition from turbulent to laminar flow. This time corresponds to a Reynolds number of approximately 3×10^6 which was used for the calculations. This transition Reynolds number is consistent with wind tunnel data which show the effect of cold walls stabilizing the boundary layer and contributing to laminar flow.

24.1.1.5.2 APS Fairing

The APS fairing was instrumented with two temperature sensors; one (C0128) was located on the centerline of the forebody and was essentially outside the vehicle boundary layer. The other (C0129) was located on the forebody 6 in. above the tank surface which placed it within the boundary layer. The temperature data show a cooling trend below the recovery temperature until approximately RO +80 sec.

The simulated temperature profile on the centerline surface agrees quite well with the data (C0128) after RO +80 sec. However, the simulated peak is some 15 sec ahead of the data in time.

The simulated temperature profile for the sensor near the tank (C0129) is approximately 50 deg R higher than the data.

24.1.1.5.3 Main Tunnel

Temperature sensor C0049 is located on the main tunnel in the region of the forward skirt where boundary layer cooling from the LH2 tank is not a factor. Therefore, the simulated temperatures were run with a transition Reynolds number of 0.5×10^6. In general, the temperature simulation on the forebody agrees well with the data except for a small time shift of the peak temperature.

The centerbody of the tunnel was instrumented with temperature sensors C0227 and C0242 along the centerline of the tunnel at DAC sta 308 and 515, respectively. Temperature sensors C0241 and C0243 were installed on the tunnel near the vehicle skin at the same respective stations. The simulated temperature profiles agree reasonably well with the data.

24.1.1.6 Base Region

24.1.1.6.1 Gas Probe Temperatures

The gas probe temperature sensors C0245 and C0246 (figure 24-8) were located on the engine thrust chamber and on the thrust structure, respectively. The temperature of the sensor on the thrust structure (C0246) increased by 130 deg R in response to the hot retrorocket exhaust gases during stage separation. The temperature probe on the engine (C0245) was shielded from direct plume impingement and only increased by 80 deg R.

24.1.1.6.2 Thrust Structure Temperature

The heating from the combined ullage and retrorocket plumes at the time of separation (figure 24-8) resulted in thrust structure temperature rises of 15 deg R and 35 deg R for C0087 and C0088, respectively. This compared to a thrust structure temperature rise of 25 deg R based on theoretical (preflight) plume heat fluxes.

24.1.1.6.3 Base Region Calorimeters

The heat fluxes measured by the calorimeters in the base region are shown in figure 24-9. The base region calorimeter C0247 located on the engine showed a relatively low heat flux of 0.4 Btu/sec-ft^2 due to retrorocket heating, indicating the shielding effect of the engine structure and plumbing.

The two calorimeters C0248 and C0249 located on the thrust structure went off-scale-high during the plume heating period as was expected. The preflight estimate of the heat flux was 3 Btu/sec-ft^2. The calorimeter range was 0-1 Btu/sec-ft^2 and was intended primarily to assess solar heating rates. The radiometer (C0250) indicated a radiative heat flux maximum of 0.19 Btu/sec-ft^2 at RO +148 sec and decreased slowly thereafter to approximately 0.05 Btu/sec-ft^2.

24.1.1.6.4 J-2 Engine Calorimeters

Two calorimeters were located on the J-2 engine bell to measure the effects of retrorocket plume heating during separation. One calorimeter (C2000) was located in line with the retrorocket exhaust and one (C2004) was located in between two retrorockets. Data obtained from these measurements in addition to the simulated heat flux profile are given in figure 24-9. Since the calorimeters had a range of 0 to 50 Btu/sec-ft^2, the indicated low output values must be assessed with reservation.

The maximum sensor output indicated by the calorimeters are 6.4 and 3.7 Btu/sec-ft^2 for C2000 and C2004, respectively. The preflight predictions indicated a maximum sensor output of 10 Btu/sec-ft^2. The analyses considered that no plume heating took place until the J-2 engine bell cleared the interstage separation plane. The data show plume heating beginning immediately after separation.

24.1.1.7 Retrorocket Impingement Heating

Three calorimeters (two on the aft interstage and one on the aft skirt) were located midway between stringers 70 and 71 to measure the heat flux distribution near the centerline of a retrorocket.

Analytical simulations of the retrorocket plume heating on calorimeters C0251 and C0252 (located at DAC sta 155 and 132, respectively) are

compared with the flight data in figure 24-10. The simulated heat flux profiles agree well with the data during the time of retrorocket firing. The analyses considered the origin of the boundary layer to be on the ramp at the initial point where the oblique shock relationships were applicable. (This method differs from the AS-201 analyses where the origin of the boundary layer was assumed to be at the plume boundary.) Parameters behind this shockwave were considered to be constant along the interstage. The transport properties were evaluated at the local reference temperature.

Turbulent heat transfer coefficients were calculated and input into a two-dimensional computer program in order to adjust the heat flux profiles for thermal capacitance. The analyses considered a time lag of 0.1 sec for the retrorocket to come to full thrust and 0.1 sec for shutdown. The data showed a much more gradual thrust decay after shutdown than this which accounts for the mismatch of simulated heat flux with data after RO +145.8 sec.

The response of calorimeter C0244 located on the aft skirt is shown in figure 24-10. Also shown in this figure are calculated perturbed (flow influenced by the shock on the aft interstage) and unperturbed (flow neglecting the influence of the interstage) heat flux histories. For this location on the aft skirt, the flow properties were taken to be those behind a normal shock and the flow was assumed to be laminar with a 10 in. running length. Fair agreement between the data and the simulation was made assuming that the plume flow was perturbed.

The discernible structural temperature increases attributable to retrorocket plume impingement are shown in table 24-1. Although there are specific differences attributable to normal data scatter, retrorocket plume heating is of the same magnitude as that encountered on AS-201.

24.1.1.8 Summary of Structural Heating

Table 24-1 provides a tabulation of the various temperature sensors showing temperature at liftoff, maximum sensor temperature, estimated maximum structural temperature, calculated maximum temperature from postflight simulation and a remarks column in which are noted structural configurations that would appreciably affect temperatures.

The longitudinal temperature distributions along the S-IVB stage are given in figure 24-11 for significant flight times: (1) liftoff, (2) RO +60 sec and (3) RO +140 sec. All of the sensors were located in line approximately 30 deg from reference plane (RP) I toward RP IV. The temperature data at the given times are connected by straight lines for clarity, and do not necessarily represent temperature gradients between the vehicle stations.

24.2 Aerodynamics

24.2.1 Compartment Pressure Differentials

The differential pressure histories for the forward skirt (DAC sta 573.0 to DAC sta 665.1) and the aft skirt and interstage (DAC sta -2.0 to DAC sta 255.0) of the S-IVB-202 stage were determined using flight and wind tunnel pressure data. Both the preflight predictions and the actual flight data include angle-of-attack effects. The predicted analytical design data are based on the planned MSFC trajectory of 15 January 1963 and the AS-202 corrected angle-of-attack data previously determined by DAC.

The forward skirt internal pressures were obtained from pressure measurement D0048. Similarly, the aft skirt and interstage internal pressure were obtained from pressure measurement D0500. These data are presented in figure 24-12.

To evaluate the differential pressure variations, it was necessary to evaluate the external pressure history. No external pressure measurements were taken on the S-IVB-202 stage. Hence, the external stage pressure distribution on the forward skirt was based on wind tunnel test data (reference: North American Aviation Report PSTL-2 dated February 1964) and on aft skirt and interstage wind tunnel test data (reference: Chrysler Report CCSD TN-AE-63-3, dated August 1963). The evaluation of both external pressure histories was based on the actual AS-202 flight trajectory data.

The evaluated flight data are presented in the form of the differential pressure histories. The forward skirt, aft skirt and interstage differential pressure histories are shown in figure 24-13. Since the external

pressure is based on pressure coefficients obtained from wind tunnel data, the data must be considered with reservation.

The postflight simulated maximum and minimum pressure differentials fall well within the predicted maximum and minimum design envelope. This design envelope is obtained by combining the extremes in internal and external pressure. The maximum differential pressure is obtained by taking the difference between maximum internal compartment pressure and the minimum pressure external to the compartment. The maximum internal pressure results from combining the effects of selected leakages, maximum internal volume, minimum internal gas temperature at liftoff and atmospheric flow past the vent orifices. The minimum external pressure is a function of station and circumferential position and depends upon the external flow field. Similarly, the minimum differential is a difference between the minimum internal compartment pressure and the maximum pressure external to the compartment. The minimum internal pressure results from combining the effects of selected leakages, minimum internal volume, maximum internal gas temperature at liftoff and not considering the effects of atmospheric flow past the vent orifices. The maximum external pressure is obtained in the same manner as the minimum external pressure, considering both station and circumferential position.

24.2.2 Plume Impingement Effects

A plume impingement anomaly occurred during S-IVB/S-IB separation which required additional analysis. Differences in the performance of the various retrorockets caused torques to be induced on the S-IB and S-IVB stages.

The forces on the S-IB stage and the S-IVB stage during S-IB/S-IVB separation due to the impingement of the retrorocket exhaust plumes were estimated and included in the separation analysis (section 15).

The retrorockets chamber pressure histories during the S-IVB/IB separation were obtained from flight pressure measurements D0153 through D0156. These pressure histories and previously determined analytically-derived forces were then used to define the force and moment histories presented in figure 24-14. This figure presents the resultant force histories acting on the interstage, and the normal and axial force histories

acting on the S-IVB stage. The center-of-pressure for the forces on the interstage was considered to be DAC sta 115. The point of application of the normal forces on the S-IVB stage was considered to be DAC sta 214 while the axial forces were considered to act 2 ft off the centerline of the S-IVB stage toward their respective motors.

24.3 Component Heating

The electronic component temperatures monitored during the flight were within allowable temperature limits.

The ground hold temperatures of the aft interstage components (bridge module No.'s 4 and 5, the LOX and LH2 chilldown inverters, and aft battery No.'s 1 and 2) were approximately 25 deg F cooler than those monitored on S-IVB-203. Temperatures of the forward interstage components (bridge module No.'s 1, 2, and 3, the propellant utilization assembly, the static inverter-converter, and forward battery No.'s 1 and 2) were approximately 5 deg F cooler. These cooler ground hold temperatures were probably due to a colder purge gas temperature for S-IVB-202 with a resultant higher convective heat loss by the components. The radiative heat loss should have been comparable for the components of both stages even though S-IVB-203 had patches of aluminized mylar applied to certain portions of the LOX dome. These patches were not near any of the components instrumented with temperature sensors.

Table 24-2 shows temperatures of the above-mentioned components which were monitored during the first 580 sec of flight. The temperature changes of the electronic components during the first 580 sec of flight were comparable to those monitored on S-IVB-203.

24.4 Propellant Heating

The net heat transferred to the LH2 during flight was analytically determined by two methods. A comparison between the results obtained from these two methods and previously calculated maximum and minimum design heating values is shown in figure 24-15.

Curve A was calculated using recovery temperature and outside heat transfer coefficient histories, based on the flight trajectory. Curve B was calculated using the average cylindrical tank skin temperature history. Maximum values of insulation thermal conductivity (k) as a function of temperature were used in both methods. These k values were determined from S-IVB loading and acceptance firing test data. The wetted areas were determined by using the LH2 mass history. The heat transferred through heat shorts (i.e., paths other than the cylindrical tank) were taken from a recent S-IVB propellant heating analysis.

As shown in the figure, propellant heating results for this flight fall within the design values.

TABLE 24-1 (Sheet 1 of 3)
TABULATED MEASURED AND POSTFLIGHT SIMULATED DATA
S-IVB-202

SENSOR NUMBER	INITIAL TEMPERATURE (°R)	MAXIMUM SENSOR TEMPERATURE (°R)	ESTIMATED MAXIMUM STRUCTURAL TEMPERATURE* (°R)	MAXIMUM CALCULATED SENSOR TEMPERATURE (°R)	ΔT FROM RETRO FIRING (°R)	REMARKS
Forward Skirt						
C0081	540	647	689	636	17	
C0082	540	597	639	636	16	
C0083	540	648	690	636	15	
C0084	540	649	703	626	11	
C0108	542	639	645	615	17	Stringer
C0109	542	625	679	626	16	
C0110	544	593	612	622	9	Stringer
C0111	523	618	673	625	11	
C0239	531	602	632	601	5	Skin over frame
C0240	509	587	607	577	0	
LH2 Tank						
C0075	510	533	535	548	1	
C0076	511	543	545	548	3	
C0077	513	558	560	548	5	
C0078	498	528	530	548	2	
C0079	494	515	517	548	1	
C0080	476	505	507	548	1	
C0106	510	543	545	548	2	
C0107	513	580	582	548	5	
C0220	500	557	559	548	4	

*Estimated true maximum temperature based on maximum sensor temperature data.

TABLE 24-1 (Sheet 2 of 3)
TABULATED MEASURED AND POSTFLIGHT SIMULATED DATA
S-IVB-202

SENSOR NUMBER	INITIAL TEMPERATURE (°R)	MAXIMUM SENSOR TEMPERATURE (°R)	ESTIMATED MAXIMUM STRUCTURAL TEMPERATURE* (°R)	MAXIMUM CALCULATED SENSOR TEMPERATURE (°R)	ΔT FROM RETRO FIRING (°R)	REMARKS
Aft Skirt						
C0045	536	621	674	607	6	
C0046	525	615	661	601	4	
C0047	535	613	663	631	4	
C0048	532	600	653	607	2	
C0113	535	593	608	591	6	
C0114	545	627	678	637	4	
C0115	548	601	626	626	3	
C0016	537	626	670	632	1	
C0117	529	626	670	632	1	
C0178	537	591	613	616	3	
C0179	530	632	683	637	16	
C0180	533	599	621	616	7	
C0181	539	624	675	637	3	
C0182	527	590	612	616	3	
C0183	532	627	678	637	7	
C0184	534	599	621	616	7	
C0185	534	633	684	637	4	
C0221	536	635	688	626	9	
C0222	531	633	677	632	7	
C0223	542	628	679	637	6	
Aft Interstage						
C0118	527	606	606	626	N/A	Covered with Korotherm
C0122	524	597	597	595	N/A	Covered with Korotherm

*Estimated true maximum temperature based on maximum sensor temperature data.

TABLE 24-1 (Sheet 3 of 3)
TABULATED MEASURED AND POSTFLIGHT SIMULATED DATA
S-IVB-202

SENSOR NUMBER	INITIAL TEMPERATURE (°R)	MAXIMUM SENSOR TEMPERATURE (°R)	ESTIMATED MAXIMUM STRUCTURAL TEMPERATURE* (°R)	MAXIMUM CALCULATED SENSOR TEMPERATURE (°R)	ΔT FROM RETRO FIRING (°R)	REMARKS
Main Tunnel						
C0049	530	715	755	712	**	Covered with Korotherm
C0227	398	475	496	598	7	
C0241	510	573	570	3		
C0242	510	598	619	610	7	
C0243	497	555	576	570	5	
APS						
C0128	545	715	775	715	**	
C0129	540	615	675	655	**	
Feed Line Fairing						
C0091	520	678	718	702	**	
Thrust Structure						
C0087	391	406	---	---	15	
C0088	393	428	---	---	35	

*Estimated true maximum temperature based on maximum sensor temperature data.

**Since temperatures were still rising due to aerodynamic heating, that portion of the rise due to plume heating was not apparent.

TABLE 24-2
SELECTED COMPONENT TEMPERATURES

COMPONENT	MEASUREMENT NO.	TEMPERATURES (°F)		
		RO	RO +145 SEC	RO +580 SEC
Fwd Battery No. 1	C0102	86	90	104
Fwd Battery No. 2	C0103	90	92	98
Static Inverter Converter	C0061	70	70	70
Propellant Utilization Assembly	C0017	58	56	58
Bridge Module No. 1	C0223	50	50	50
Bridge Module No. 2	C0234	56	53	53
Bridge Module No. 3	C0235	53	50	50
Bridge Module No. 4	C0236	12	12	8
Bridge Module No. 5	C0237	2	2	2
Bridge Module No. 6	C0238	59	44	34
LOX Chilldown Inverter	C0139	14	14	8
LH2 Chilldown Inverter	C0140	24	28	13
Aft Battery No. 1	C0104	80	82	82
Aft Battery No. 2	C0105	88	102	120

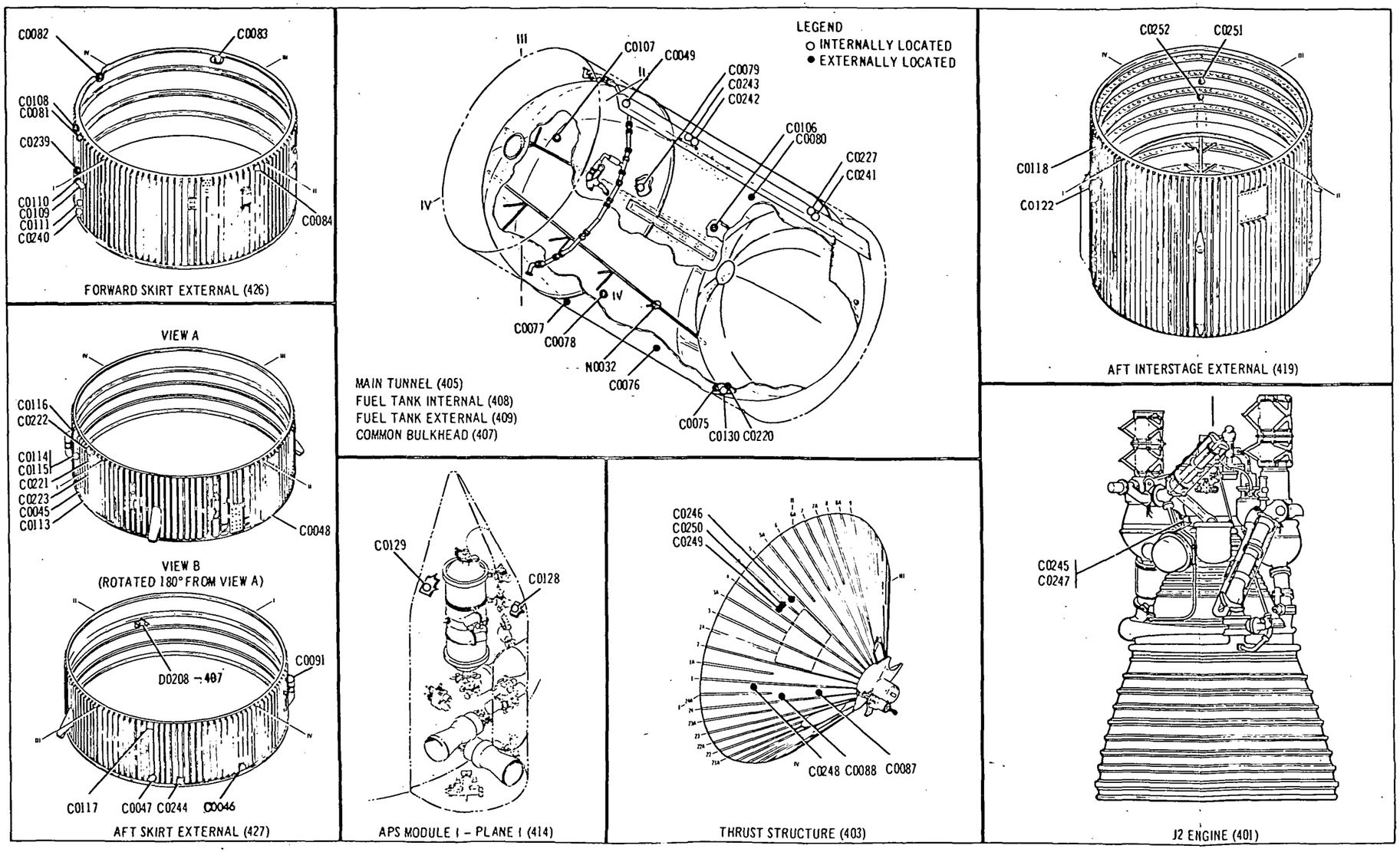


Figure 24-1. Aero/Thermodynamics S-IVB-202 Instrumentation

24 October 1966

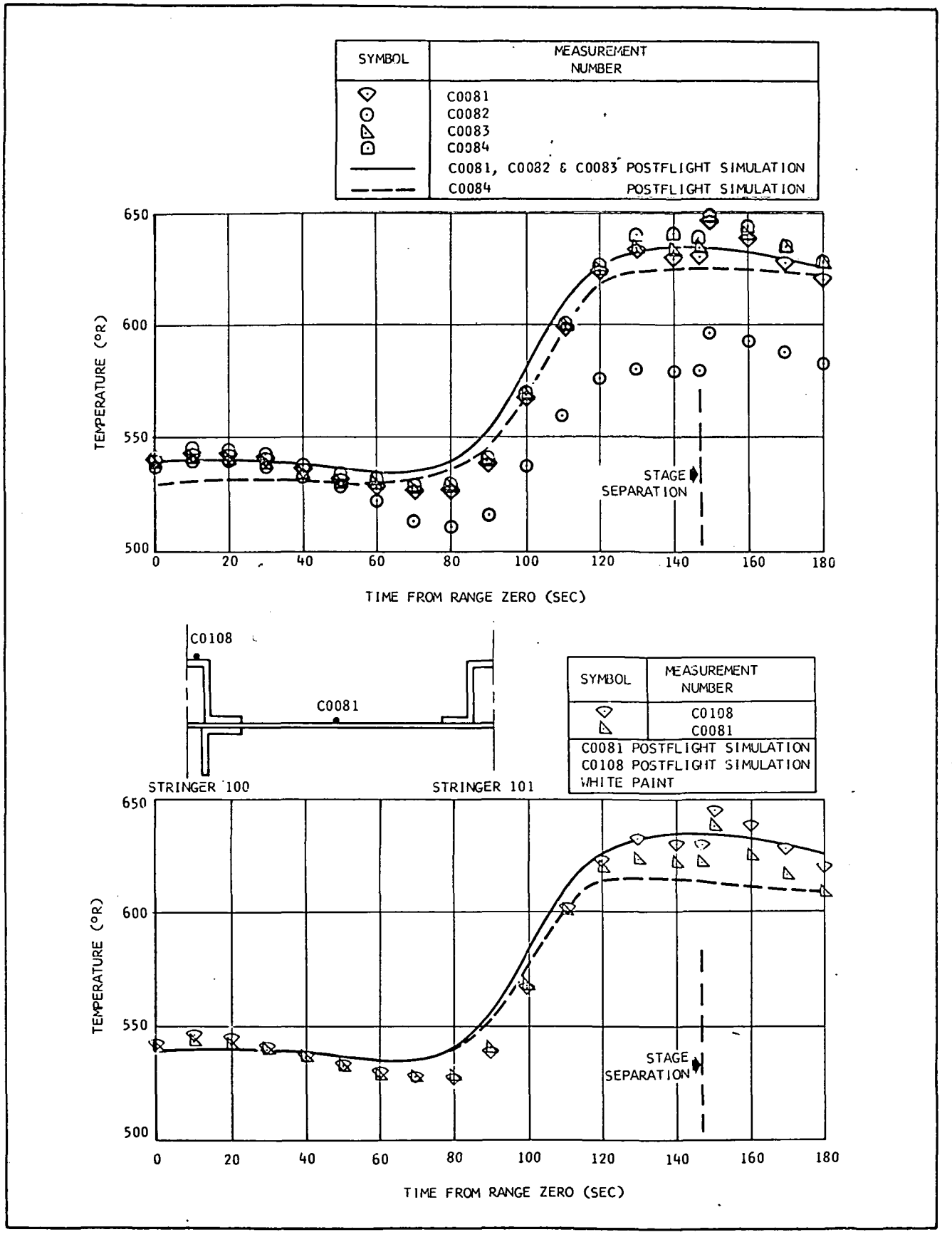


Figure 24-2. Forward Skirt Skin and Stringer Temperature at DAC Sta 671

24 October 1966

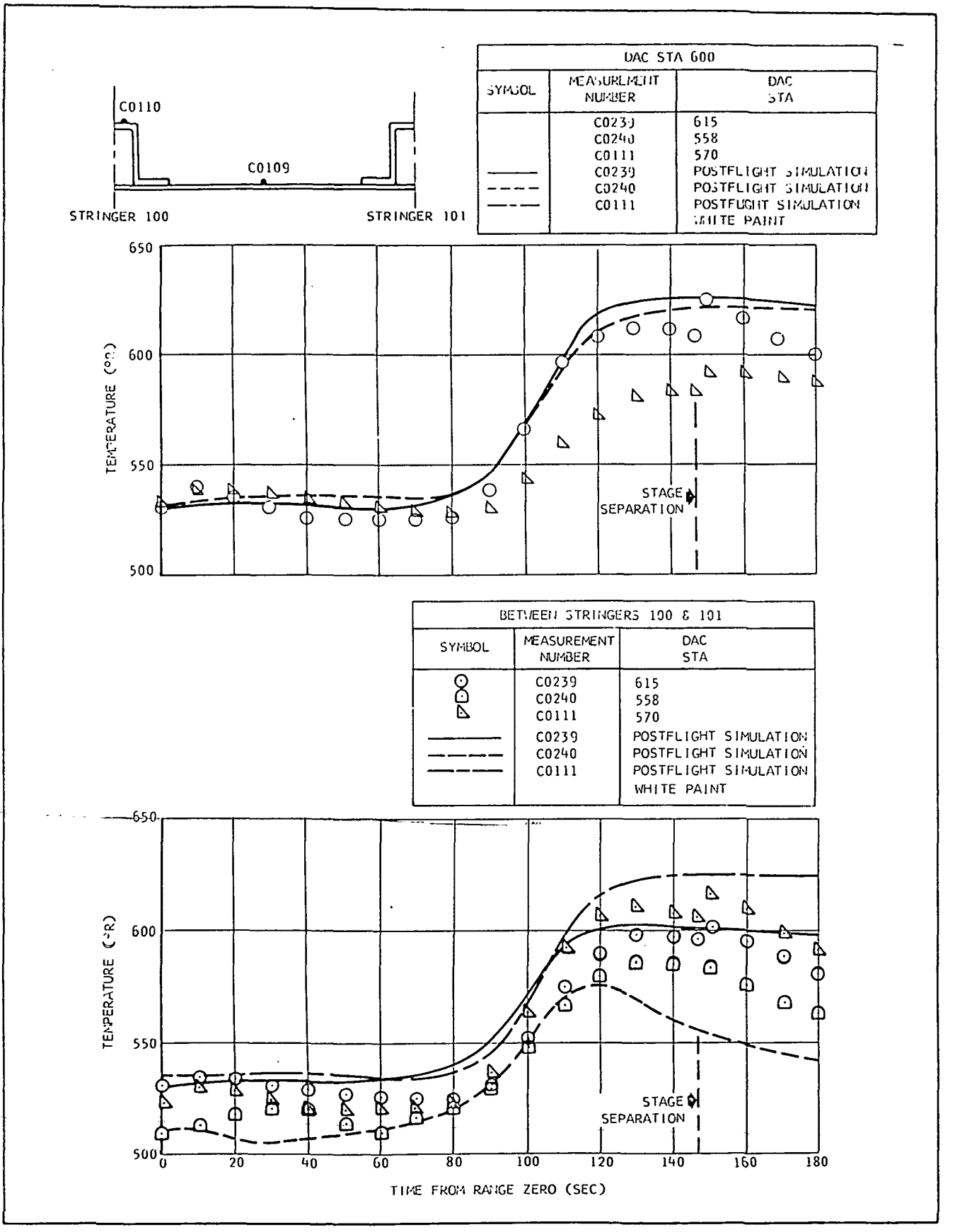
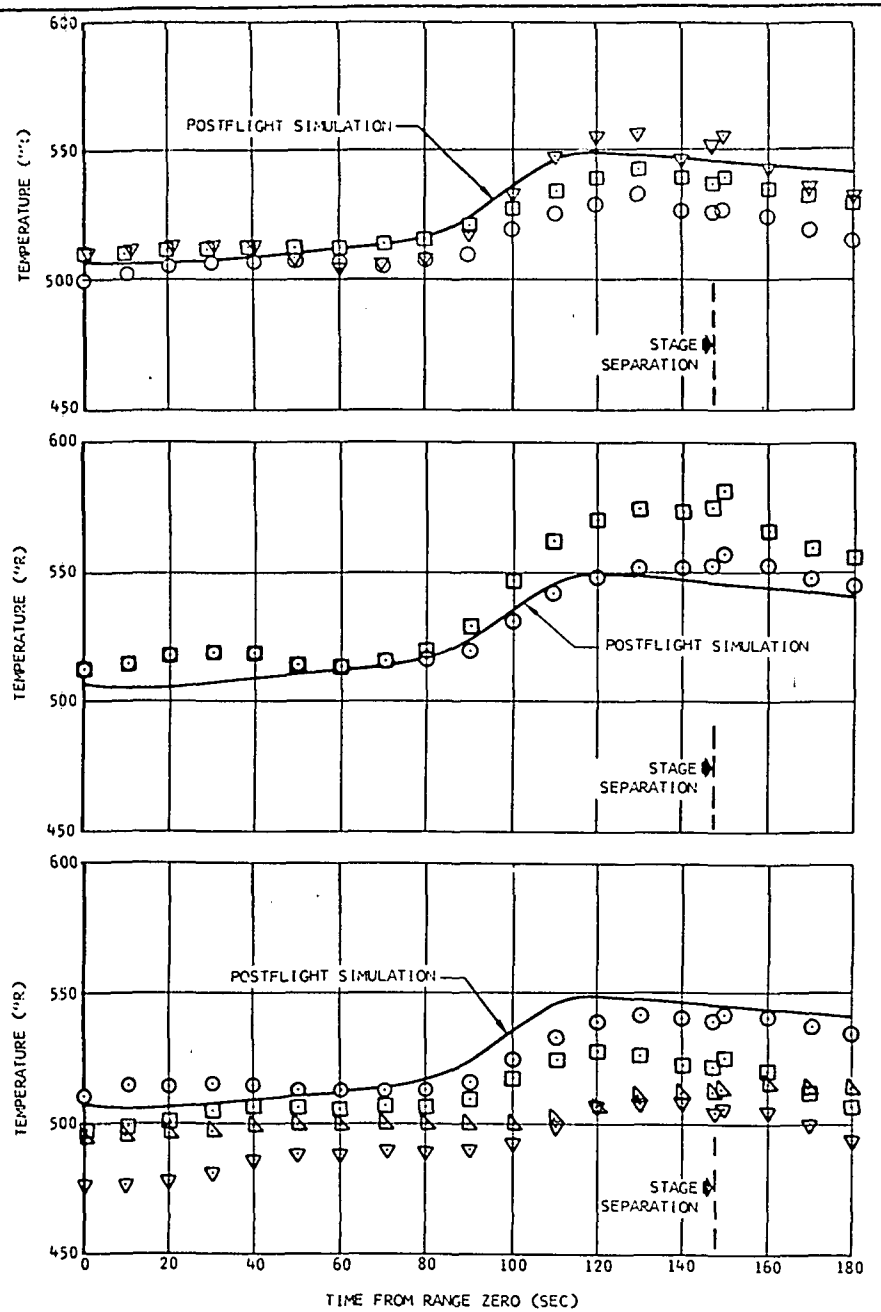


Figure 24-3. Forward Skirt Skin and Stringer Temperature

24 October 1966



SYMBOL	MEASUREMENT NUMBER	LOCATION
⊙	C0075	30° FROM RP 8 - IV (STA.
□	C0106	30° FROM RP III - IV 296)
▽	C0220	RP I, STA. 293
	WHITE PAINT	

NEAR DAC STA 545		
SYMBOL	MEASUREMENT NUMBER	LOCATION
⊙	C0077	30° FROM RP I - IV
□	C0107	30° FROM RP III - IV
	WHITE PAINT	

NEAR DAC STA 422		
SYMBOL	MEASUREMENT NUMBER	LOCATION
⊙ □	C0076, C0078	30° FROM RP I - IV RP IV
△ ▽	C0073, C0080	30° FROM RP III - IV RP II
	WHITE PAINT	

Figure 24-4. LH2 Tank Skin Temperatures

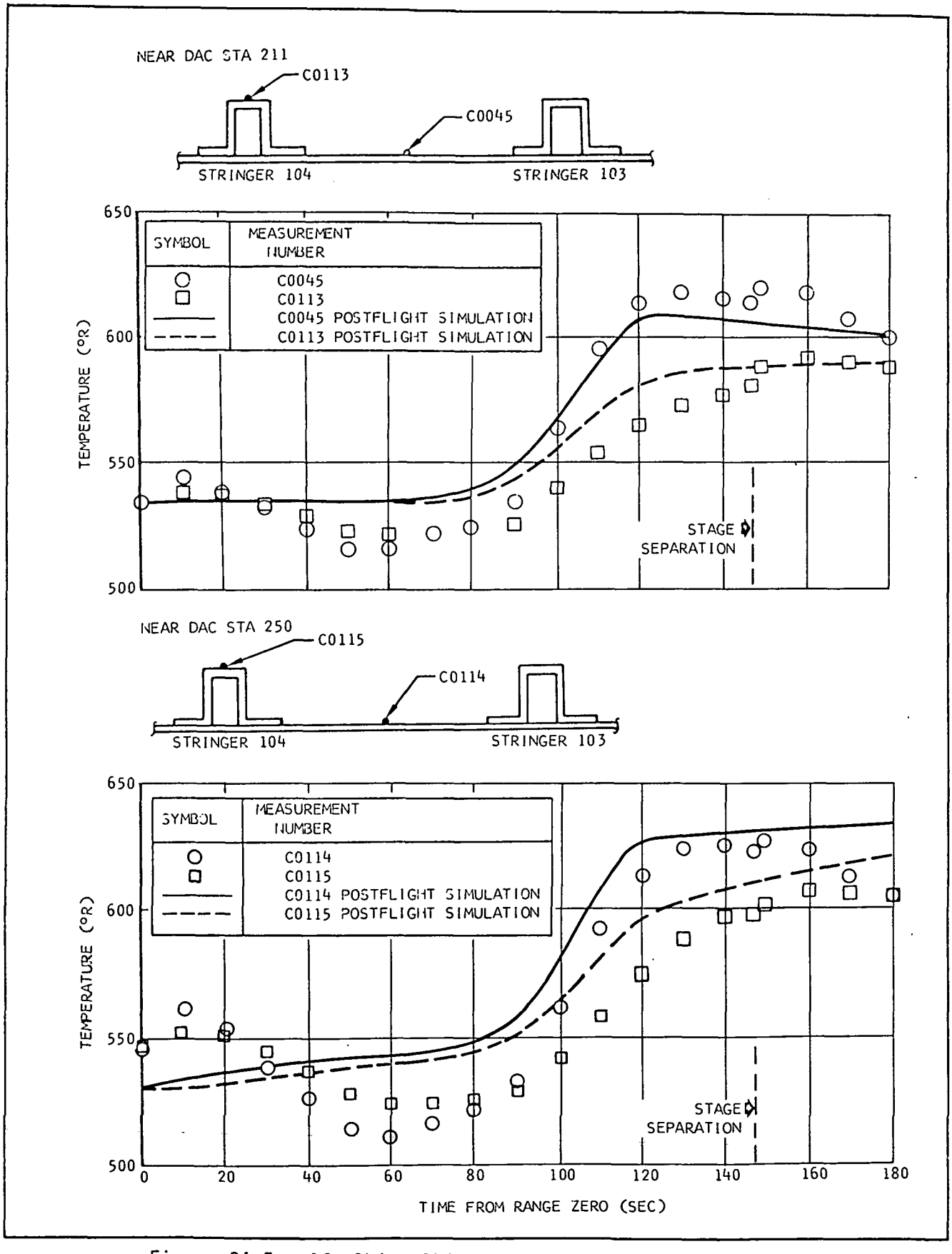


Figure 24-5. Aft Skirt Skin Temperatures (Sheet 1 of 3)

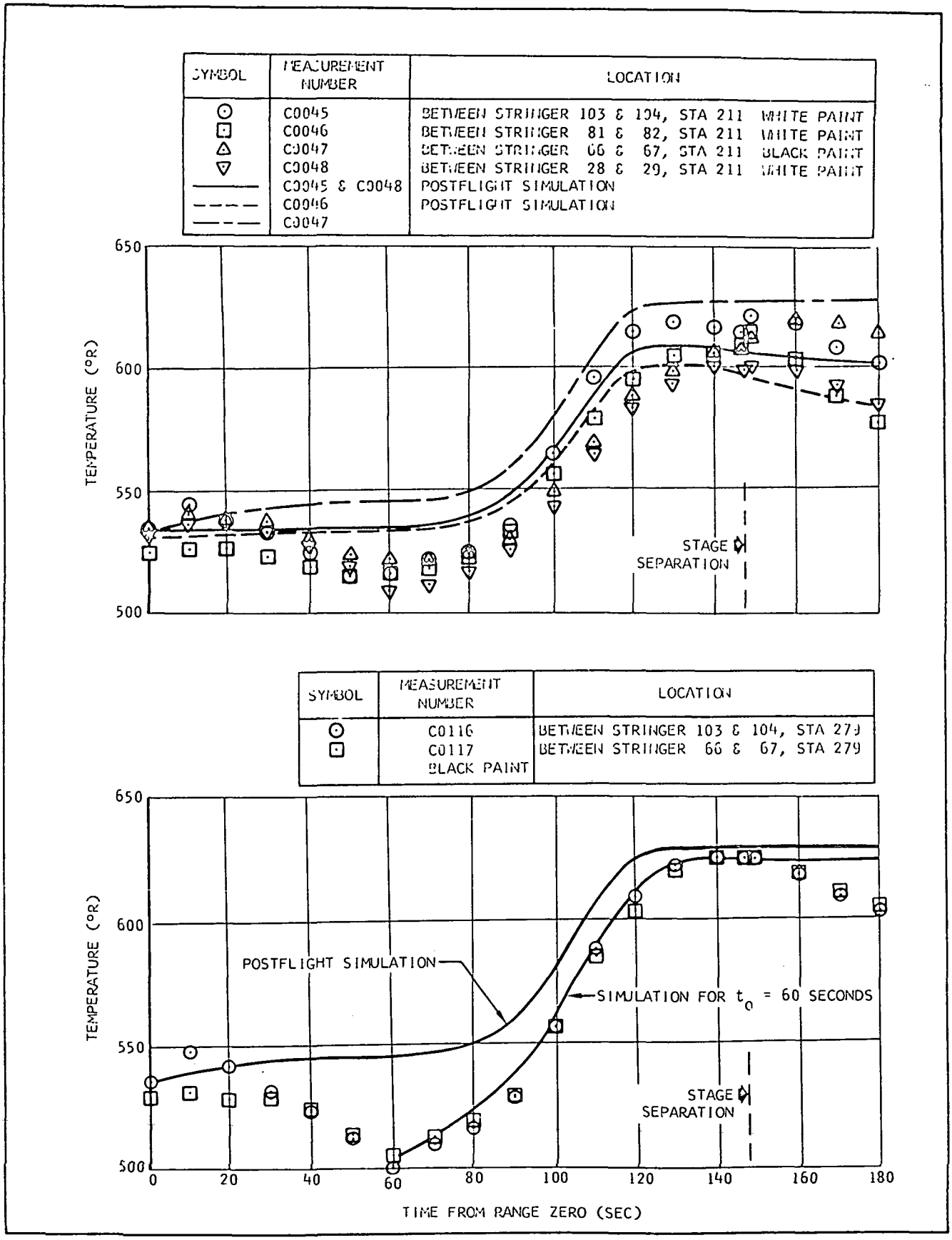


Figure 24-5. Aft Skirt Skin Temperatures (Sheet 2 of 3)

24 October 1966

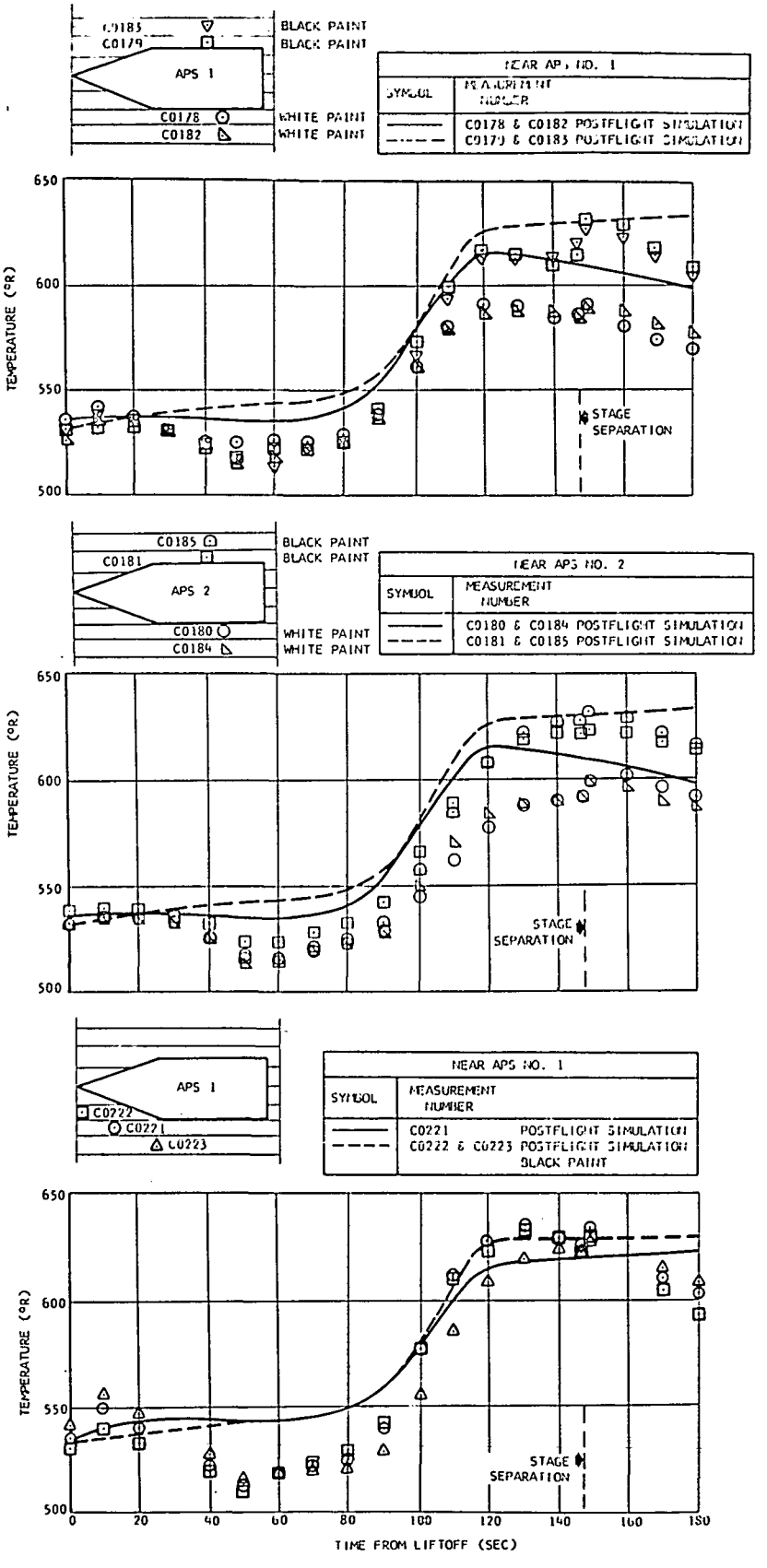


Figure 24-5. Aft Skirt Skin Temperatures (Sheet 3 of 3)

24 October 1966

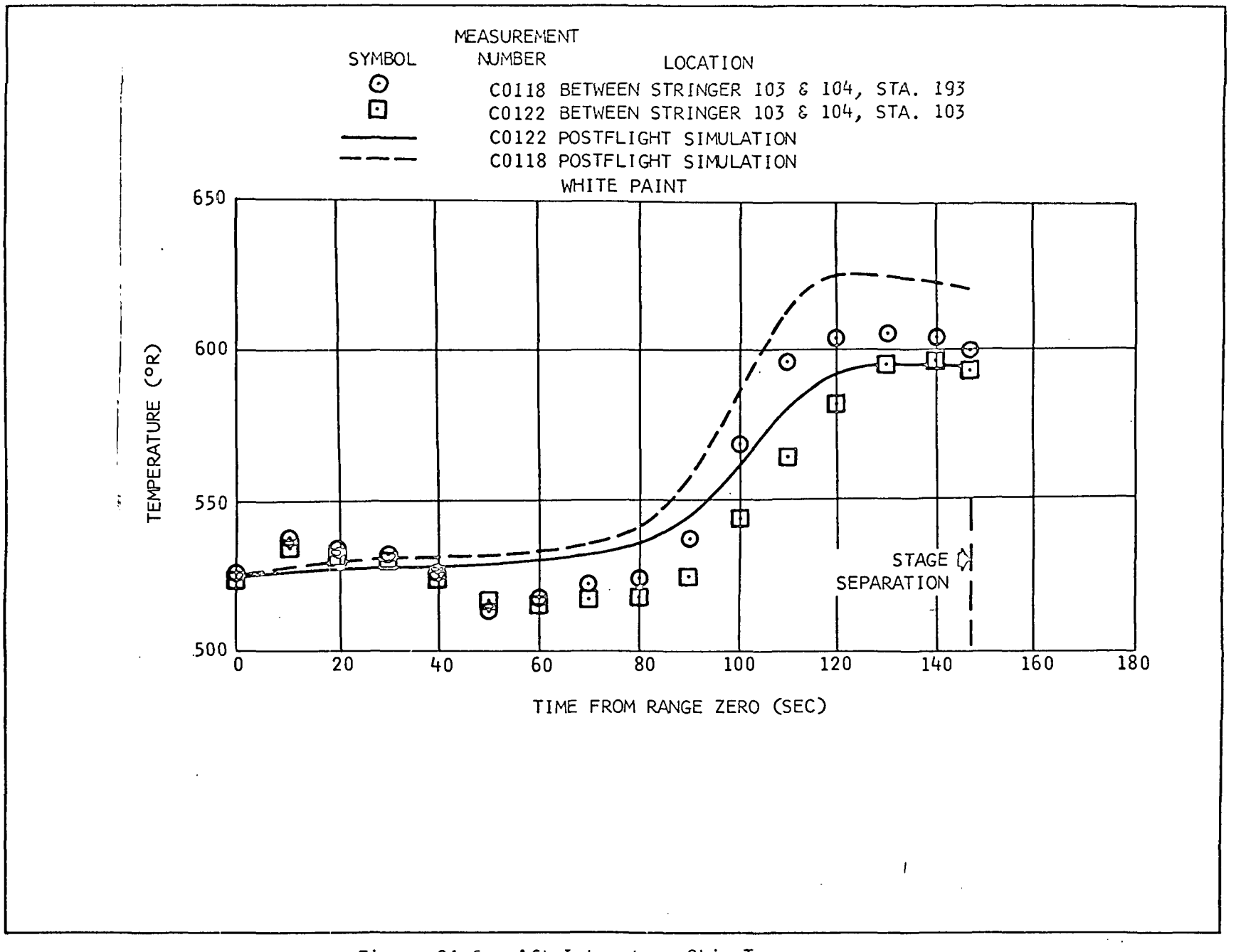


Figure 24-6. Aft Interstage Skin Temperature

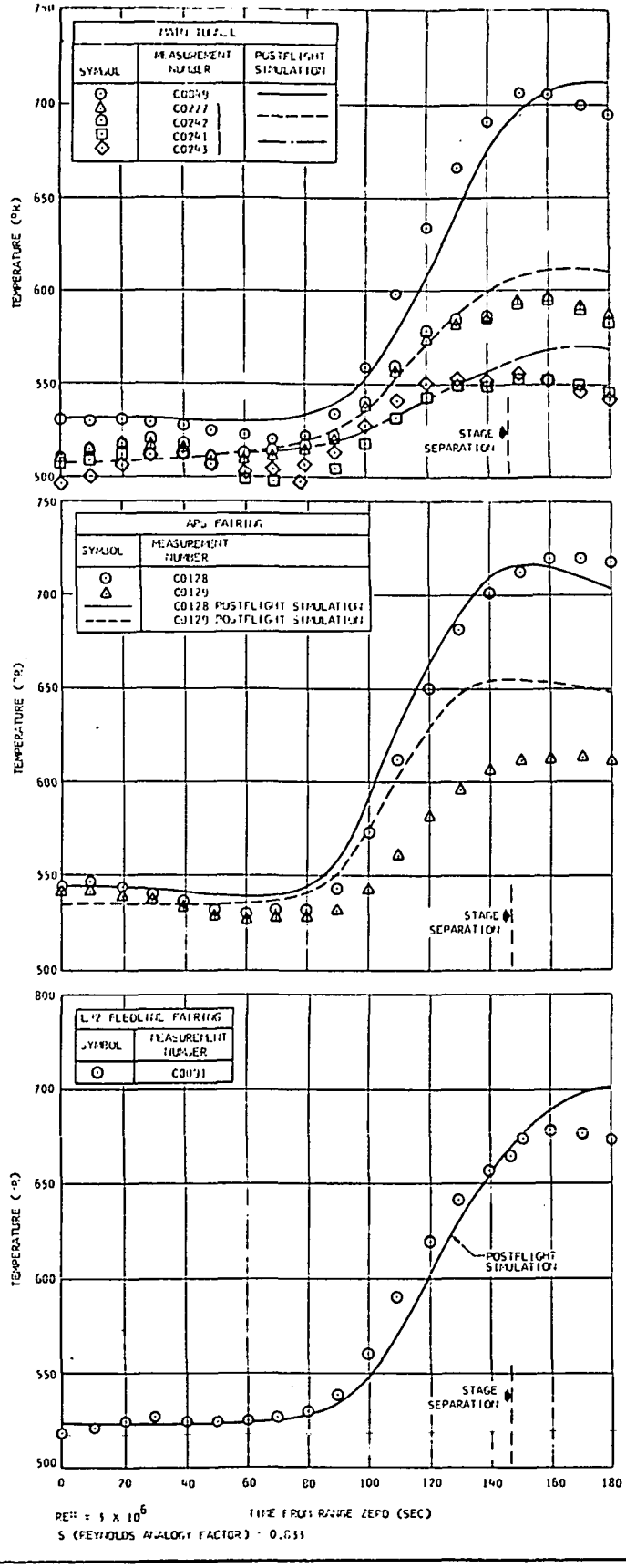


Figure 24-7. Protuberance Temperatures

24 October 1966

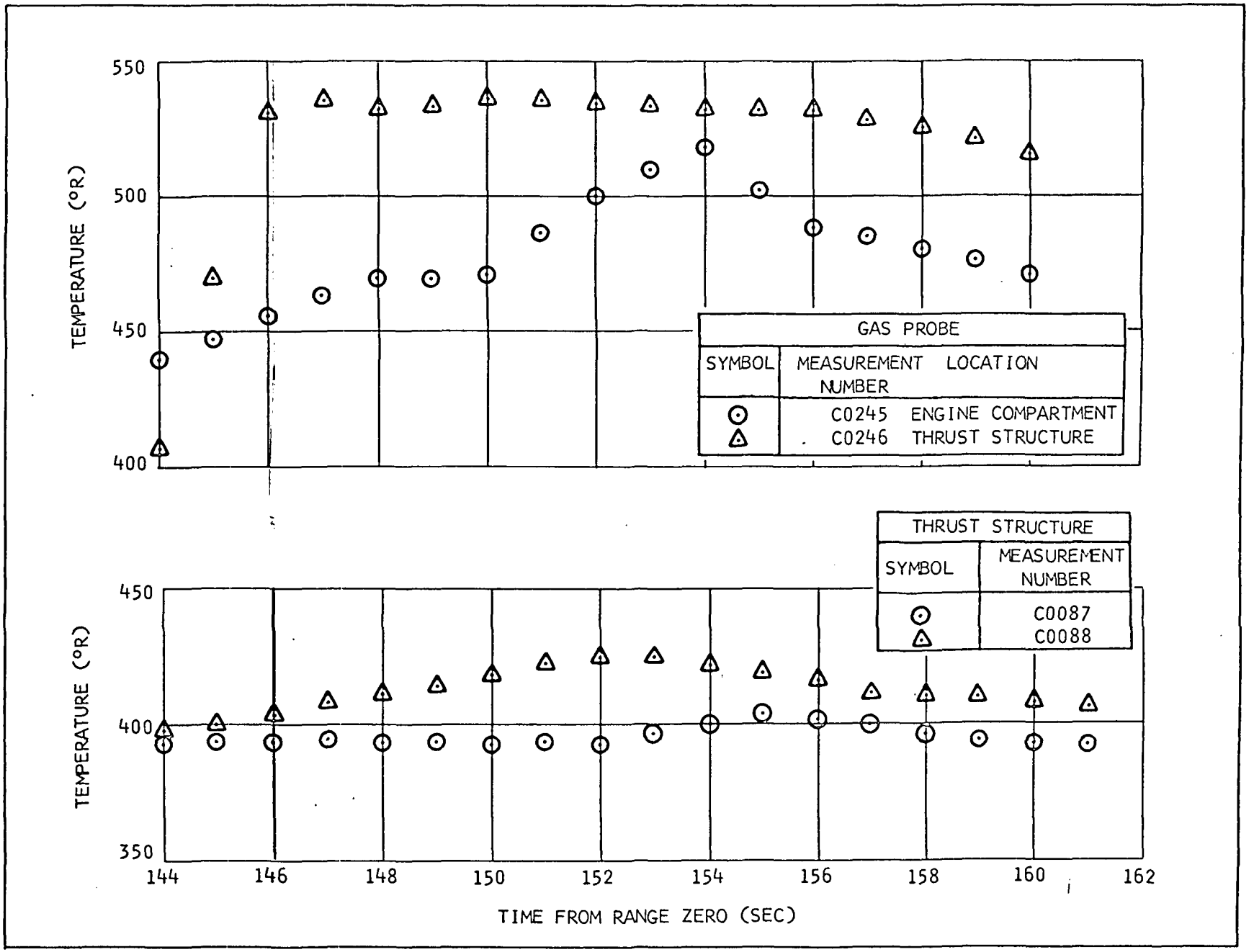


Figure 24-8. Gas Probe and Thrust Structure Temperature

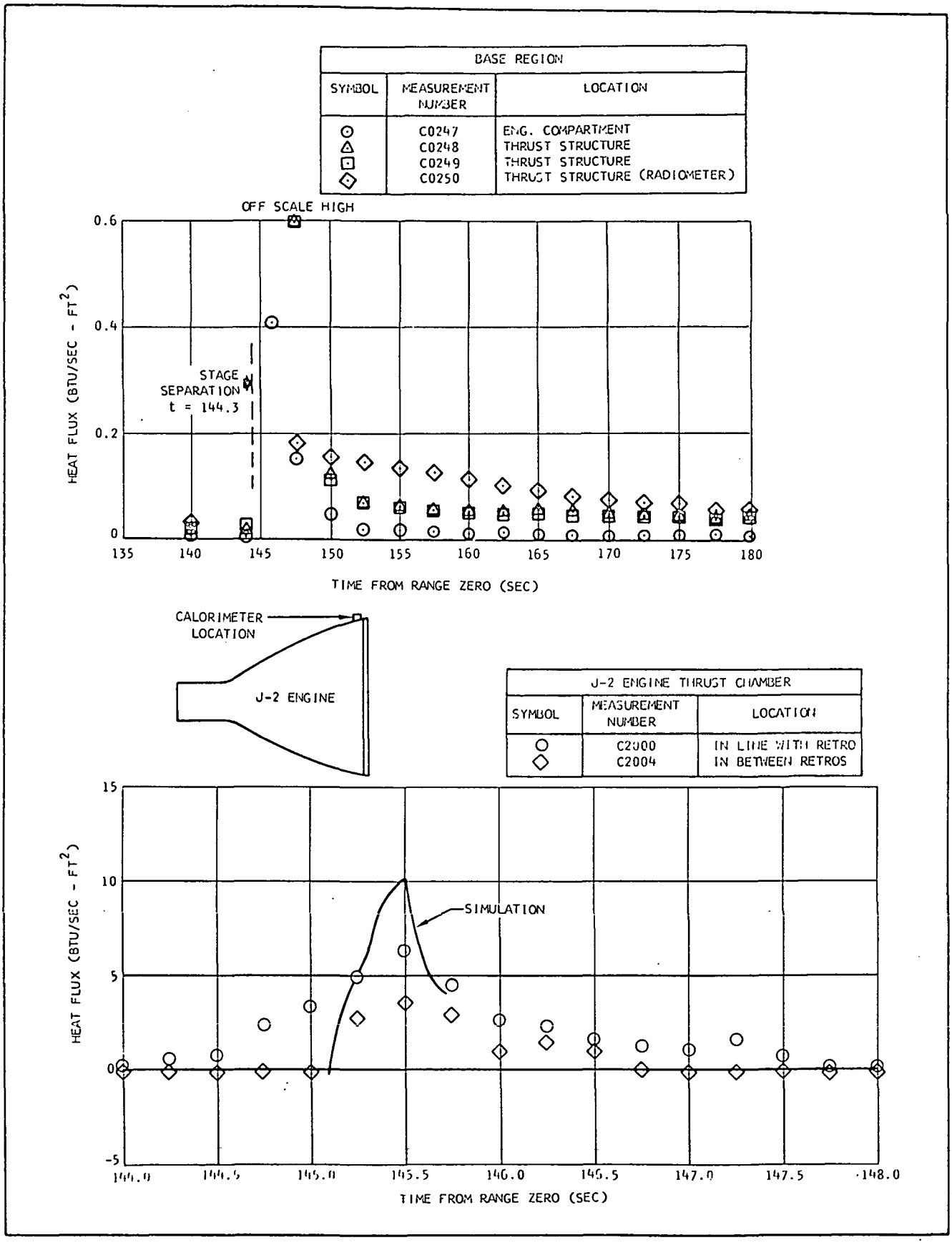


Figure 24-9. Base Region and J-2 Engine Calorimeters

24 October 1966

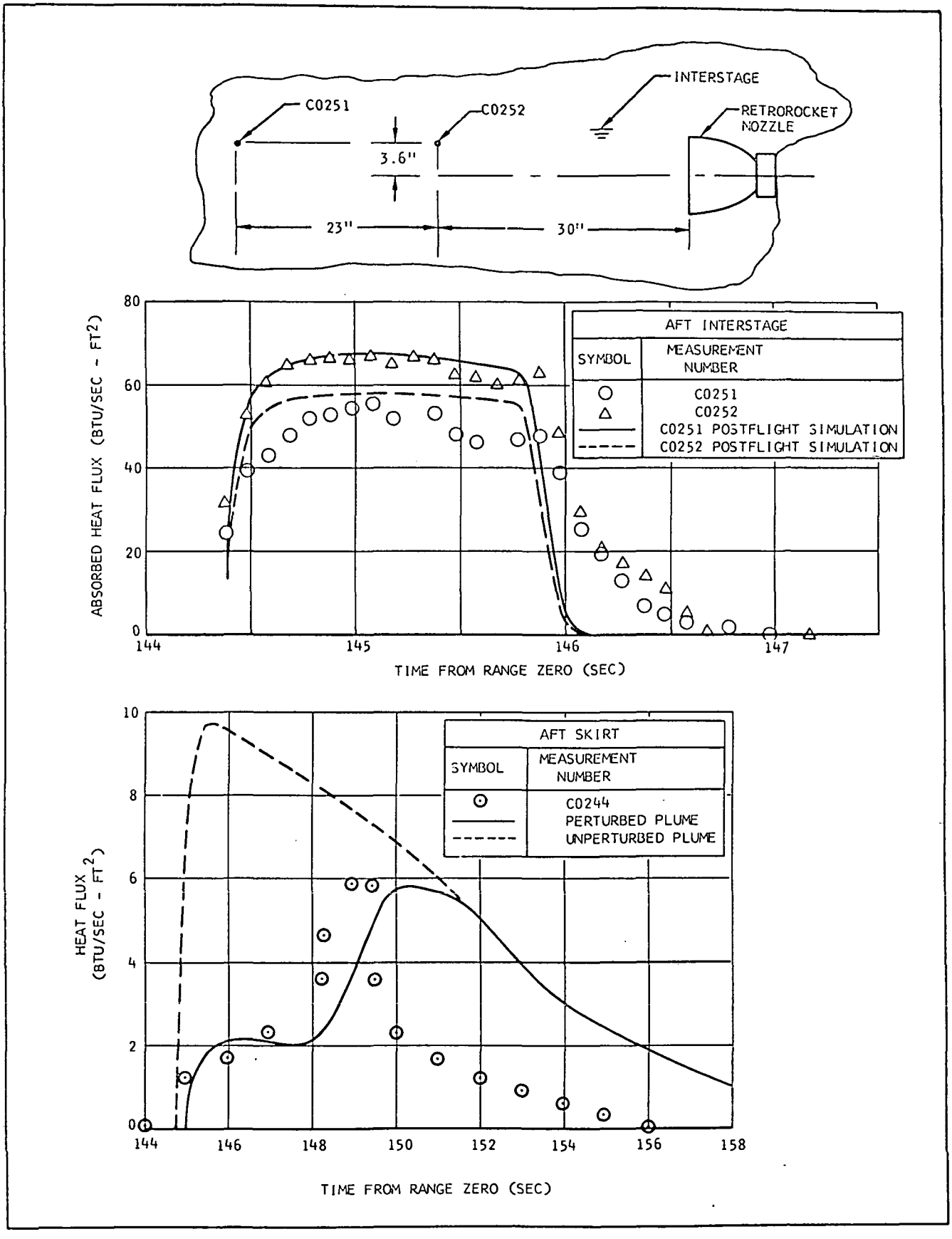


Figure 24-10. Aft Interstage and Aft Skirt Heat Flux

24 October 1966

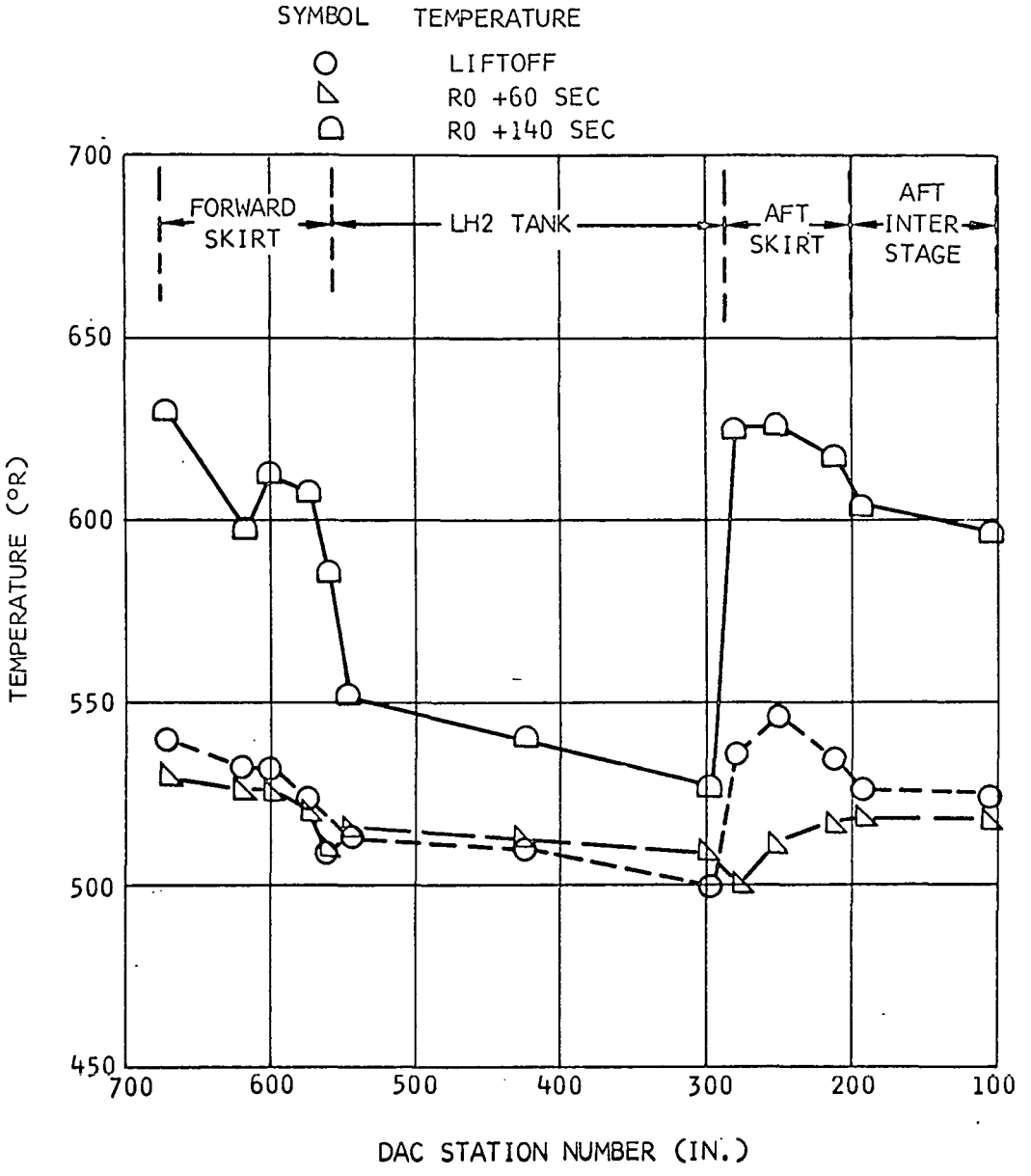


Figure 24-11. Longitudinal Temperature Profile

24 October 1966

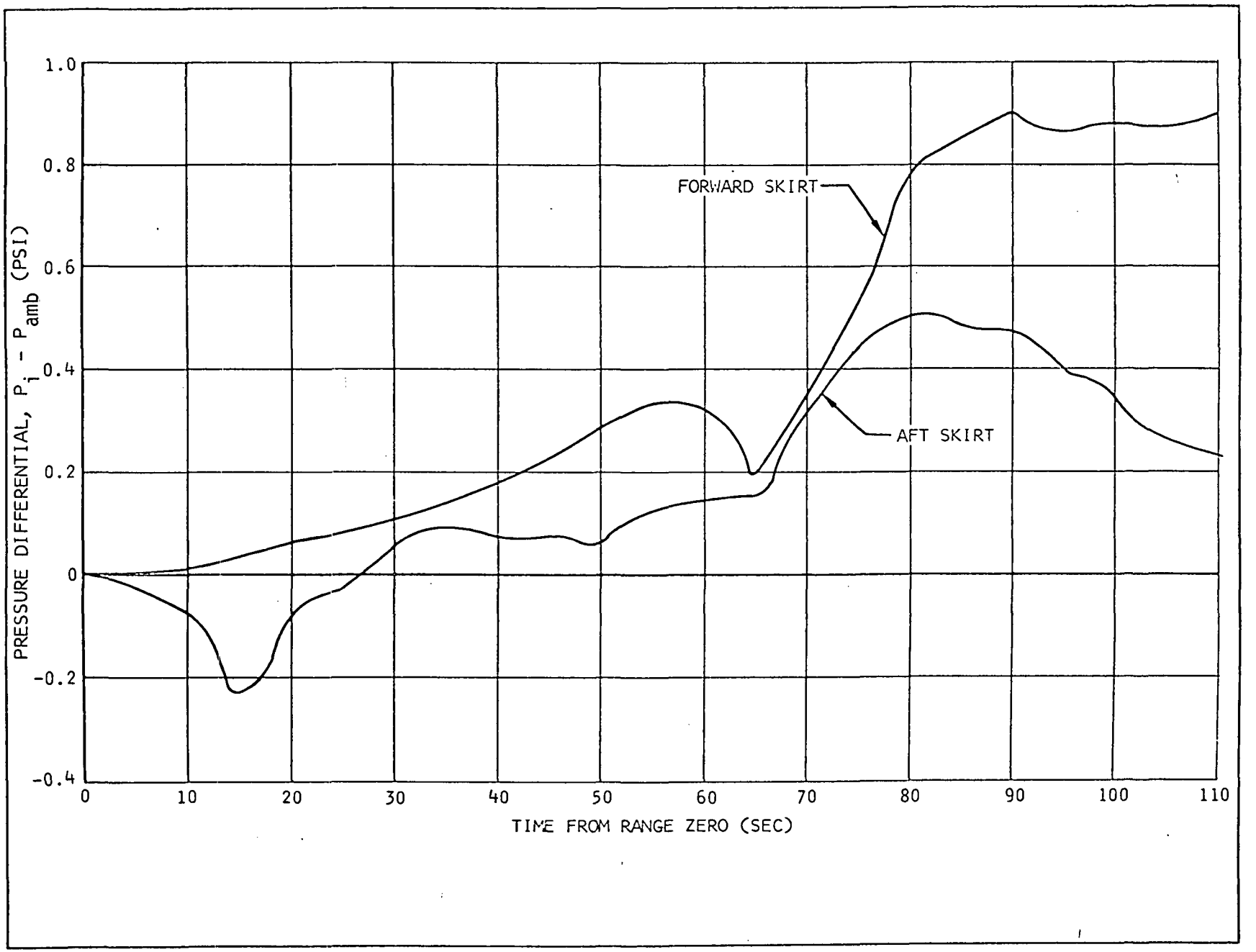


Figure 24-12. Forward and Aft Skirts Internal Pressure Relative to Ambient

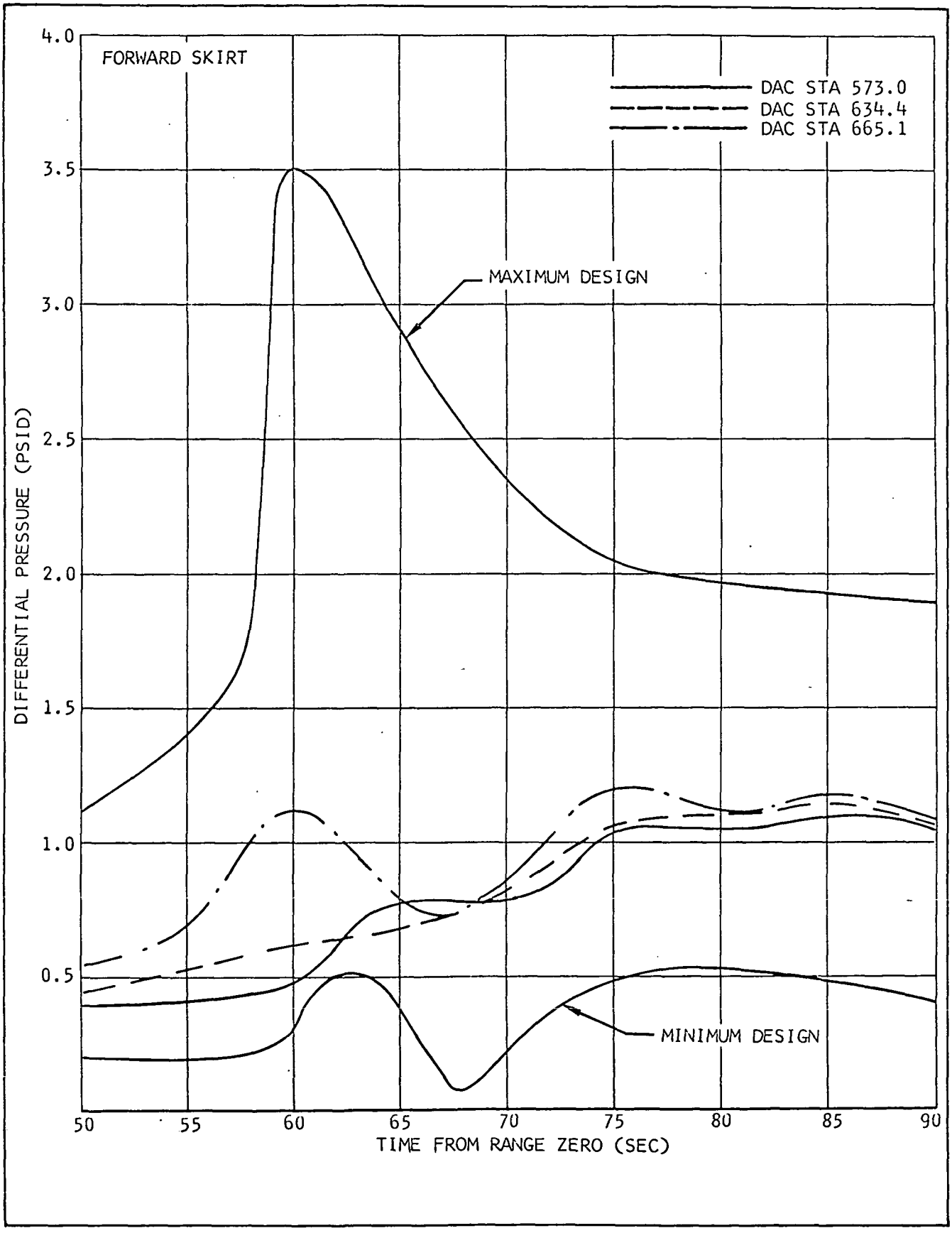


Figure 24-13. Forward Skirt, Aft Skirt, and Interstage Differential Pressures (Sheet 1 of 2)

24 October 1966

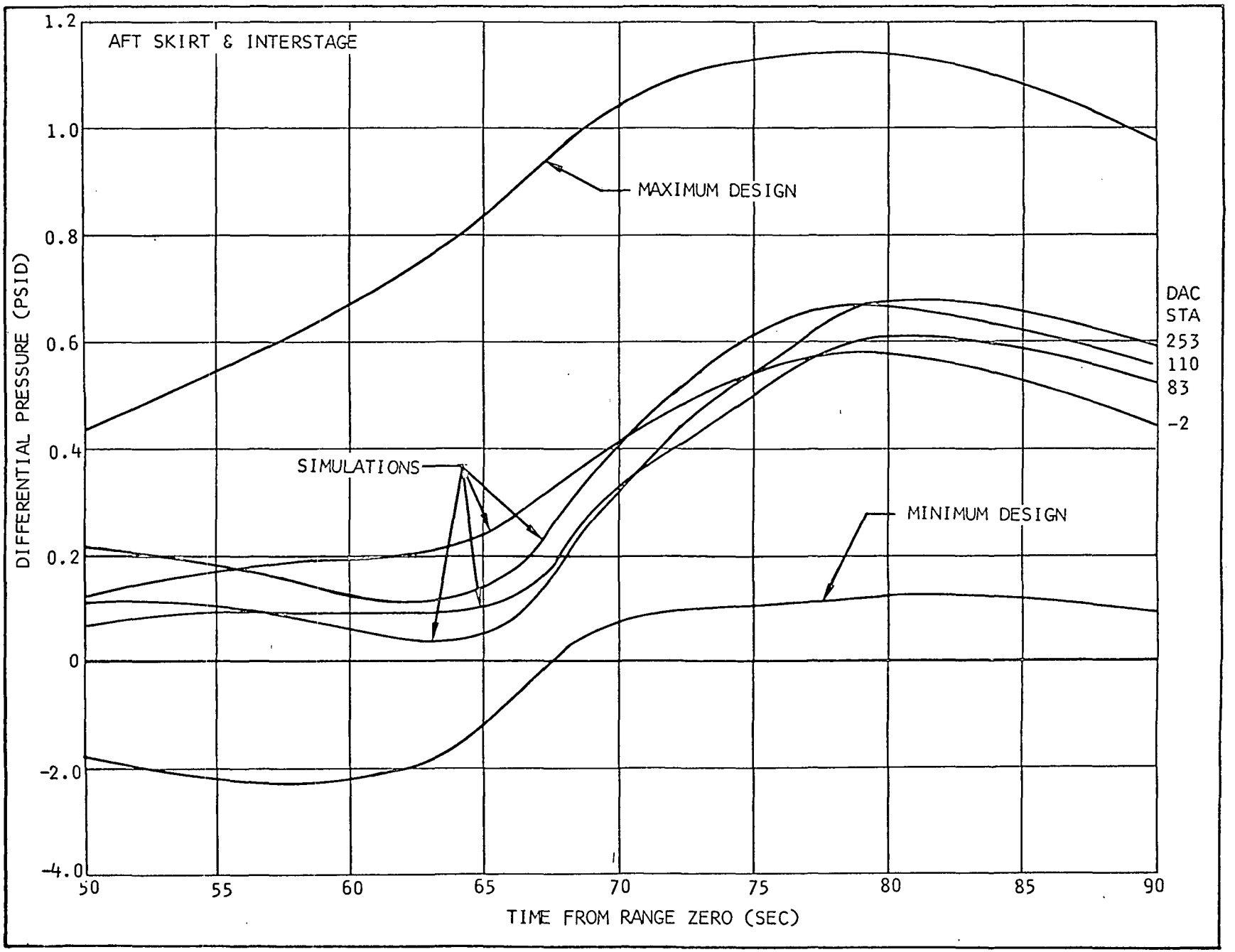


Figure 24-13. Forward Skirt, Aft Skirt, and Interstage Differential Pressures (Sheet 2 of 2)

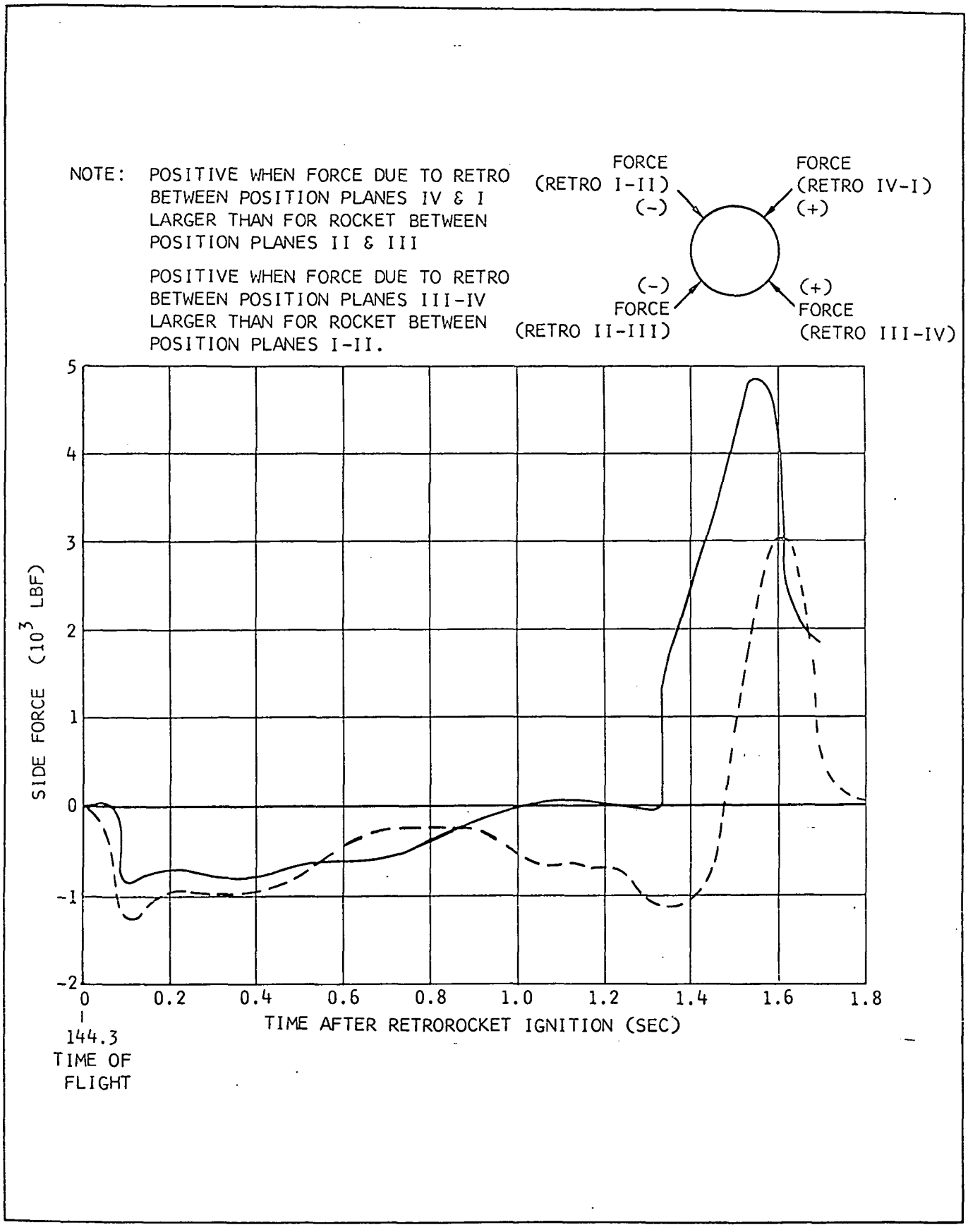


Figure 24-14. Force History on the S-IVB Stage Due to Retrorocket Plume Impingement (Sheet 1 of 2)
24 October 1966

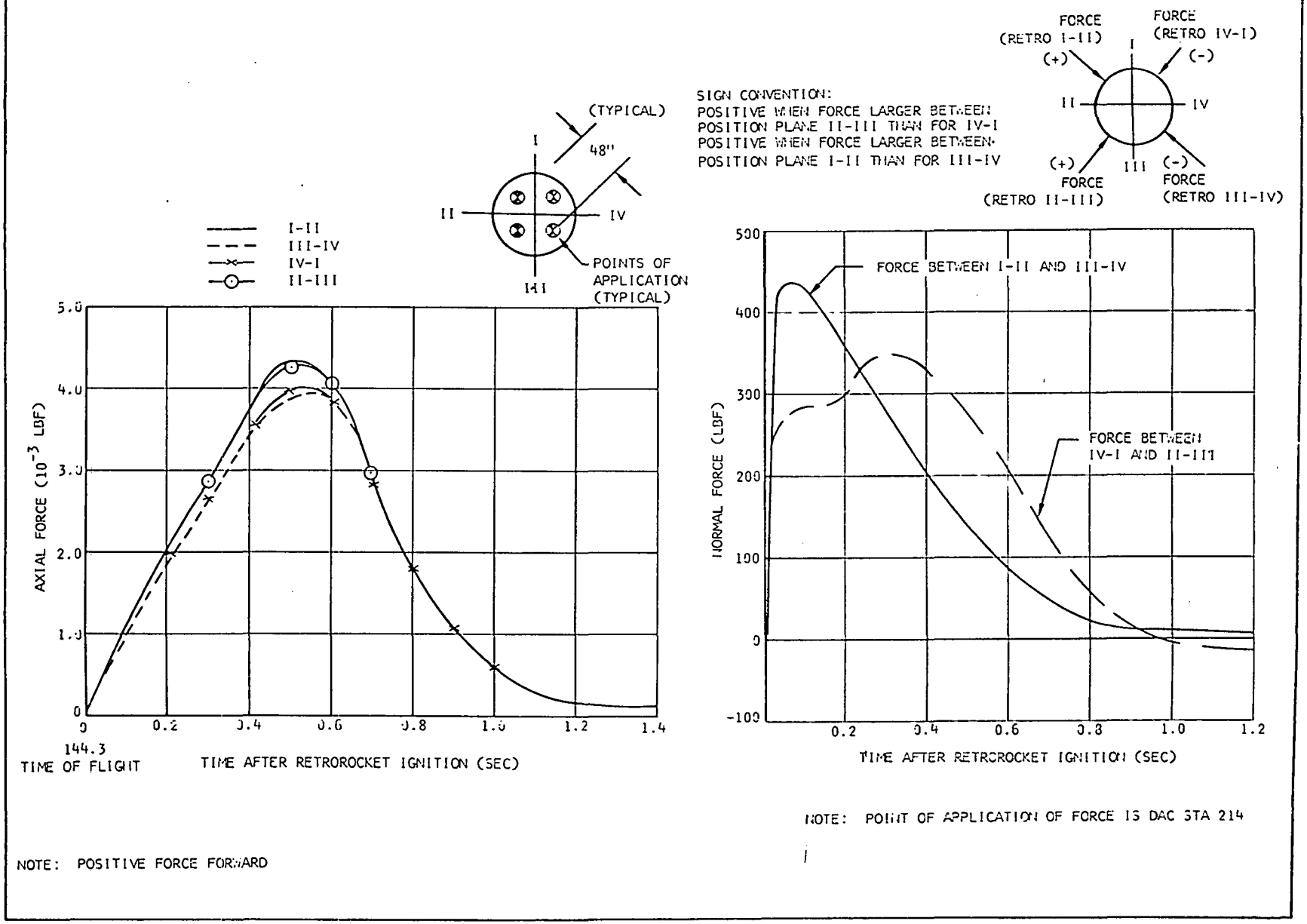


Figure 24-14. Force History on the S-IVB Stage Due to Retrorocket Plume Impingement (Sheet 2 of 2)

SUMMARY OF RESULTS

AREA	CURVE A (BTU) PRE-PRESS	CURVE A (BTU) EXIT	CURVE B (BTU) PRE-PRESS	CURVE B (BTU) EXIT
CYLINDER TANK	11,130	40,270	11,130	36,360
SHORTS	5,870	15,100	5,870	15,100
SUB-TOTAL	17,000	55,370	17,000	51,460
TOTAL	72,370		68,460	

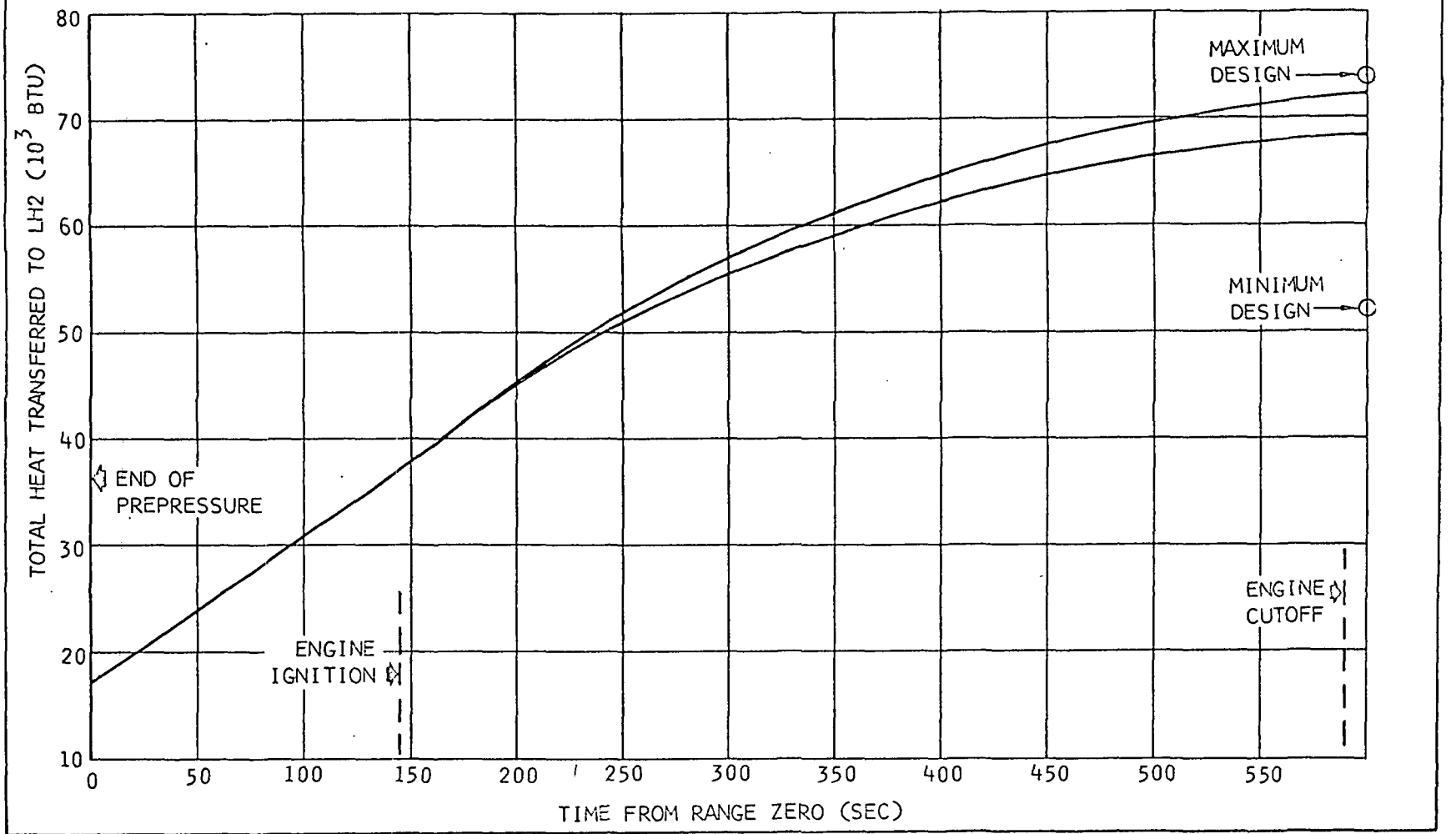


Figure 24-15. Total LH2 Propellant Heating

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25. SUB-ORBITAL COAST PHASE ANALYSIS

All stage systems performed satisfactorily during the sub-orbital coast phase. Of special interest during this period were the common bulkhead structural integrity experiment and the effects of command service module (CSM) separation. Both are discussed in this section.

25.1 Common Bulkhead Experiment

The common bulkhead structural integrity was maintained throughout the pre-launch, boost, and powered flight portion of the AS-202 flight. Investigation of LH2 and LOX tank pressures indicated no detrimental pressures across the common bulkhead. The largest pressure differential recorded across the common bulkhead prior to the pressure rise test was -12 psid due to LOX tank venting just after S-IVB engine cutoff. This differential pressure was relieved approximately 21 sec later (approximately RO +610 sec) when the LH2 ullage pressure collapsed (figure 25-1). The collapse of ullage pressure was due to propellant-ullage mixing resulting from a negative g load created by service propulsion system engine plume impingement on the S-IVB stage after CSM separation. This occurrence is explained in greater detail in paragraph 25.2.2.

Shortly after CSM separation, the LOX tank vent was again opened to allow a steady buildup of negative pressure differential across the common bulkhead until a structural failure occurred. This test was conducted to verify the structural capability of the bulkhead. After the LH2 ullage pressure collapse, the LH2 tank pressure rose continuously until loss of signal (LOS). The LH2 tank ullage pressure at this time was 36.5 psia. The LOX tank ullage pressure decayed after the vent valve was opened to 4.0 psia at LOS. Therefore, the common bulkhead differential pressure reached a nominal failure value of -32.5 psid at LOS. All recording telemetry stations reported LOS simultaneously at approximately RO +941 sec. From this it is concluded that LOS was a result of common bulkhead structural failure and the negative differential failure pressure was 32.5 psid.

Within the tolerances of the telemetry system, this value compares favorably with the failure of the common bulkhead on S-IVB-203 and experimental vehicle 9003. The common bulkhead failures of S-IVB-203 and 9003 were at a

nominal differential pressure of -34.5 psid and -33.3 psid, respectively. For a single prelaunch malfunction on man-rated vehicles (S-IVB-204 and subs), the maximum ultimate design ΔP is -30.7 psid at the common bulkhead to aft dome joint. The common bulkhead cavity vacuum pressure ranged between 0 and +1 psia during the operational period of the stage. There was no indication of a rise in internal pressure just prior to failure as occurred with the common bulkhead failure on experimental vehicle 9003. There was no indication of an internal pressure rise prior to failure on AS-203.

The following tabulation is a summary of common bulkhead tests and the related margins of safety.

Vehicle No.	Common Blkhd Ult. (Test)	Common Blkhd Ult. (Design)*	Margin of Safety
201	--	-30.7 psid	--
202	-32.5 psid	-30.7 psid	.06
203	-34.5 psid	-30.7 psid	.12
9003	-33.3 psid	-30.7 psid	.08

* Prelaunch malfunction for man-rated vehicles (S-IVB-204 and subs)

It is apparent from analysis of flight data that the common bulkhead has shown itself to be capable of withstanding an operational malfunction of the LOX tank vent system within the limit of the LH2 tank relief valve for prescribed periods of time. It has also been shown that the common bulkhead is able to withstand the maximum ultimate design reverse differential pressure for a prelaunch malfunction condition. The common bulkhead has, therefore, proven its capabilities once again and is considered structurally adequate. This additional verification is significant in operational modes and also in orbital coast modes when the S-IVB stage remains attached to the payload.

25.2 Propellant Tank Conditions

25.2.1 LH2 Tank Conditions

The LH2 tank was not vented after engine cutoff. All phenomena that occurred within the tank between ECC +21 sec and ECC +36 sec were the result of stage negative acceleration. During the period from engine cutoff to ECC +21 sec, the LH2 tank ullage pressure slowly increased from 41.1 psia to

41.5 psia while the ullage temperatures remained near 220 deg R, except for the 20 percent level which was 194 deg R at engine cutoff and decreased to 40 deg R by ECC +15 sec (figure 25-2). At ECC +21 sec SPS engine exhaust impingement upon the S-IVB stage caused a negative acceleration of the stage. This induced a distribution of liquid hydrogen throughout the ullage, thus cooling the latter. The ullage temperatures dropped rapidly to 40 deg R, and the ullage pressure decreased sharply to 28.4 psia (figure 25-1).

After the period of negative acceleration, the pressure and temperatures stabilized temporarily until, at ECC +50 sec, the ullage pressure began a very slow increase while the ullage temperatures remained near 40 deg R. The ullage pressure stabilized briefly at ECC +90 sec when the LOX vent was opened. Ullage temperature at the 20 percent level (C0034) had increased to 70 deg R at this time. Subsequently, the ullage pressure increased to 36.5 psia by ECC +352 sec (R0 +941 sec) when the common bulkhead failed. At failure the ullage temperatures at the 100, 90, and 70 percent levels had increased to 80, 46, and 56 deg R, respectively, while all measurements lower in the tank remained at, or decreased to 40 deg R.

25.2.2 LOX Tank Conditions

The LOX tank was vented twice after engine cutoff, and the ullage pressure reached a minimum of 4.0 psia at common bulkhead failure. From ECC +0.9 to +8.4 sec, the LOX vent was opened to decrease the ullage pressure and eliminate the possibility of LOX tank venting during spacecraft separation from the S-IVB stage. During this vent, the ullage pressure decreased from 38.0 psia to 29.4 psia, and the ullage temperature measurements all indicated decreases due to lowering pressure and resultant boiloff (figure 25-2). The ullage pressure increased to 31.0 psia after the vent was closed and before the stage experienced negative acceleration at ECC +21 sec. During this period the ullage temperatures at the 101 and 100 percent levels increased to 240 and 250 deg R, respectively, while the lower temperature measurements continued to indicate a decreasing trend. This probably occurred because the effect of boiloff was greater on measurements closer to the liquid surface. At ECC +21 sec, SPS engine exhaust impingement upon the S-IVB caused the stage to experience a negative acceleration for a period of 15 sec. This resulted in the dispersion of the LOX residual throughout the ullage and the

sudden drop of the ullage temperatures to 165 deg R (saturation temperature). During this period the ullage pressure increased slightly to 31.5 psia and stabilized as the ullage temperatures remained at 165 deg R. The pressure increase, in spite of the decreasing temperatures, is the result of LOX boiloff more than compensating for ullage collapse.

At ECC +90 sec, the LOX vent valve was commanded open; the ullage pressure was 31.5 psia and the ullage temperatures averaged 165 deg R. Subsequently, the ullage pressure decreased steadily to 4.0 psia by ECC +352 sec. At this time the common bulkhead experienced a differential pressure of -32.5 psid and failed. All ullage temperatures remained off-scale low (below 157 deg R) except for C0135 (101 percent level) which decreased to 136 deg R and stabilized during this final period.

25.3 Stage Systems Performance

25.3.1 Stage Pneumatic Control System

The stage pneumatic control system satisfactorily supplied control helium to the LOX and LH2 vent valve actuators during the suborbital flight.

The regulator output pressure was maintained between 505 and 525 psia throughout the period of recorded data except for the usual momentary pressure drops that occurred during valve actuations (figure 25-3). Between engine cutoff and ECC +7 sec, the control helium sphere pressure decreased from 2,605 to 2,465 psia as a result of closing the LH2 and LOX prevalves and opening the LH2 tank vent valve. The prevalves were expected to open 60 sec after Engine Cutoff Command, however, they remained closed throughout the duration of the coast phase. The valves failed to open as a result of a sequence error external to the S-IVB stage. The LOX vent valve was reopened at ECC +90 sec and maintained open. The actuation of these valves resulted in high helium usage rates during the coast phase. The rates were as follows:

Time Interval	LOX Tank Vent Valve Position	Helium Usage Rate (scfm)
ECC to ECC +7 sec	Open	30.48
ECC +7 to ECC +98 sec	Closed	4.21
ECC +90 to ECC +352 sec	Open	2.38

Although helium usage was high, the system performance was satisfactory for the S-IVB-202 mission.

25.3.2 Cold Helium Spheres

During the suborbital coast period, the mass (187 lbm) in the cold helium spheres remained constant as the spheres heated and then cooled. Following engine cutoff, the sphere pressure increased from 1,200 psia to 1,235 psia as the flow from the spheres was terminated and temperatures increased 5 to 10 deg R. The pressure and temperatures dropped when liquid hydrogen splashed through the tank ullage during the period of negative acceleration and cooled the spheres (figure 25-4). After the liquid was settled, sphere pressure and temperature continued to decrease until ECC +250 sec. At this time they stabilized near their cutoff values of 1,060 psia and 56.5, 54.5, 53.2, and 50.0 deg R (spheres 5, 3, 2, and 1, respectively).

25.3.3 APS Thermal Control System

The passive thermal control system of the APS adequately maintained all propellants and components within the allowable temperature limits throughout the flight. Flight instrumentation indicated that the propellant temperatures were between 544 and 549 deg R during the suborbital coast phase which is well within the allowable values.

25.4 Vehicle Forces and Motions

The forces affecting S-IVB stage motion during the coast phase were as expected with the exception of the effects of SPS plume impingement.

During CSM/S-IVB separation, ignition of the SPS engine caused large forces on the S-IVB stage due to plume impingement. Data obtained from MSFC were used to establish these forces.

The chamber operating conditions for the SPS engine were used to compute the plume properties and flow field. Newtonian Hypersonic Impact Theory was used to obtain the forces on the S-IVB/IU/SLA stage with the SLA panels deployed. The results of this analysis indicated that at SPS ignition, plume impingement resulted in an axial force in excess of 15,000 lbf acting on the S-IVB stage.

25.4.1 Flight Control System

The AACS performed satisfactorily during the orbital coast period of flight performing all required maneuvers and maintaining control in the presence of external disturbances, even the unusually large disturbance generated by the SPS plume impingement on the S-IVB stage.

The vehicle attitude errors and rates during orbital coast are shown in figure 25-5; the corresponding APS firing history is shown in figure 25-6. Significant events are labeled on these figures. Loss of real time FM and PAM telemetry occurred during the inflight tape recorder playback in the interval from RO +627 sec to RO +655 sec.

The total impulse used from J-2 engine cutoff (588.5 sec) through final loss of telemetry signal (940.9 sec) was 4,645 lb-sec for module 1 and 6,227 lb-sec from module 2. These values include estimated impulse usage during the interval of data loss.

Table 19-2 shows a summary of APS pulses and impulse consumption for powered flight and orbital coast of the S-IVB-202 vehicle. Figure 25-7 presents the total impulse consumption per module as a function of flight time.

25.4.1.1 Transients Induced by Main Engine Cutoff, LOX Vent, and CSM Separation Disturbances

The S-IVB J-2 engine cutoff occurred at RO +588.5 sec, followed closely by opening of the LOX tank vent at RO +589.26 sec. The LOX vent, coupled with the cutoff transient, produced the pitch, yaw, and roll vehicle disturbance shown in figures 25-8 and 25-9. No AACS activity occurred, until AACS pitch and yaw channels were activated at RO +593.76 sec. Immediately thereafter, engines I_{II} and III_{II} came full-on to correct for the yaw disturbance followed closely by intermittent pulses from engine I_p to correct for the pitch disturbance (figure 25-6). At RO +596.79 sec the LOX vent was terminated, and at RO +596.97 sec the S-IVB/CSM separation was initiated; an additional pitch disturbance was attributed to this separation and caused engine I_p to fire again to correct for the disturbance. At approximately RO +600 sec, engines I_{IV} and III_{IV} fired.

The total number of pulses (all pulses were not minimum pulses) occurring during this portion of the orbital coast was 60 pulses from module 1 and 31 pulses from module 2. The impulse used during this time was 1,098 lb-sec for module 1 and 722 lb-sec for module 2 (table 19-2).

A simulation of the flight from RO +592 sec to S-IVB/CSM separation (RO +597 sec) was made to determine the LOX vent thrust disturbances. The vehicle characteristics used in the simulation are shown in table 25-1. The actual and simulated attitude errors and angular velocities are shown in figures 25-8 through 25-10.

The LOX vent angle was varied to obtain simulated AACS impulse requirements corresponding to the impulse requirements experienced during flight. The impulse usage for this period is tabulated in table 25-2 for the flight and for the two simulations. One simulation was made with nominal vent angles; the other simulation was made using the maximum radial vent angle tolerance (-3 deg) at the nozzle attach point. (See figure 19-7 for the LOX vent orientation.) The simulation using the maximum vent angle tolerance produced results which corresponded reasonably well with the flight data.

The phase of flight from S-IVB/CSM separation to RO +610 sec was simulated to determine the control system response during S-IVB/CSM separation. The simulation results shown in figures 25-8 through 25-10 were obtained using initial vehicle attitudes, angular rates, and the non-nominal LOX vent angle discussed previously. The actual vehicle angular velocities shown in these figures indicate disturbing moments around RO +600 sec which is attributed to the S-IVB/CSM separation. No effort was made to simulate the S-IVB/CSM separation. The AACS responded satisfactorily to control disturbances during this time interval. The actual and simulated APS impulse usage for the noted time interval is tabulated in table 25-3. The simulated impulse usage and system response do not correlate with flight data since the disturbing moments occurring at S-IVB/CSM separation were not included in the simulation.

25.4.1.2 SPS Engine Plume Impingement-Caused Transient

At RO +610 sec, during SPS ignition, the vehicle pitch and yaw attitude

errors were driven 3.45 deg in the positive pitch direction and 2.4 deg in the positive yaw direction; engine I_p fired to correct for the pitch disturbance and engines I_{II} and III_{II} fired to correct for the yaw and roll disturbance. The disturbance was apparently caused by SPS thrust plume impingement on the deployed LEM adapter panels; the forces from impingement created a torque unbalance which caused the above attitude errors. Less than 2 sec after SPS ignition, the LEM adapter panels III and IV were blown off or folded back thus shifting the center of pressure of the plume impingement to the opposite side of the S-IVB cg and reversing the moments generated by the impingement. The resulting pitch, yaw and roll attitude errors reached maximum values of -61.9, -29.2 and -23.5 deg, respectively. This resulted in sudden shutoff of APS engines I_p, I_{II} and III_{II} and an immediate firing sequence of engines III_p, III_{IV} and I_{IV}. Engine III_p fired continuously through loss of data beginning at RO +627 sec. Real time FM and PAM data was lost at this time for approximately 28 sec during the S-IVB separation recorder playback. Engine III_{IV} fired continuously to RO +623.2 sec after which it fired continuously up to RO +623.2 sec after which it fired intermittently until loss of data at RO +627 sec. Engine I_{IV} fired continuously up to RO +625.9 sec after which it also fired intermittently to loss of data at RO +627.0 sec (figure 25-6).

The total impulse used during this transient was 2,210 lb-sec by module 1 and 5,642 sec by module 2. These included estimated impulse usage during the recorder playback portion of the flight (RO +627 to RO +655 sec) during which loss of data occurred. These estimates were made from APS propellant consumption data (table 19-2).

The orbital coast phase of the AS-202 flight was simulated during the interval from RO +610 sec to end of flight. The initial period of this simulation is of particular interest because of the high disturbing moments imparted to the S-IVB-IU configuration following spacecraft separation.

The vehicle body angular velocities were differentiated to determine the angular accelerations. These accelerations were used to determine the

initial vehicle disturbing moment inputs to the simulation. The disturbing moments were adjusted to simulate the angular velocities experienced during flight. Figure 25-11 presents the disturbing moments which were used in the latest simulations and are considered representative of those actually experienced in flight during the spacecraft thrust plume impingement disturbance.

Figures 25-8 through 25-10 present the pitch, yaw, and roll attitude rates, respectively, obtained from flight data during the SPS impingement on the S-IVB-IU. These figures also show the simulated attitude rate using the disturbing moments shown in figure 25-11. These simulated rates are considered to be representative ofactual rates experienced although the angular deviations in putch and yaw are less and the roll higher than those experienced during flight. The roll angular velocity is difficult to simulate because of the cross-coupling between the yaw and roll control systems.

Figure 25-5 shows a comparison of pitch, yaw, and roll attitude rates obtained from flight data and from simulations for the period from J-2 engine cutoff to end of flight. The AACS impulse usage determined from flight data and from simulations for the time period RO +610 sec to RO +650 sec are tabulated in table 25-3. The maximum S-IVB-IU angular excursions due to the SPS impingement are tabulated in table 25-4. The AACS performed satisfactorily during and following the impingement disturbance. The APS engines fired to counter the disturbing moments and continued to fire until the system maximum angular velocities defined by the attitude error limits had been achieved. The large attitude errors were then decreased at these rates until the errors were within their limits. The AACS was then able to control the vehicle as determined by the attitude error signals from the LVDC and the angular velocity signals from the body rate gyros.

25.4.1.3 LOX Tank Blowdown

At approximately RO +678.7 sec the LOX blowdown was initiated. This caused engine I_{IV} to fire intermittently until the pitch, yaw and roll maneuver was initiated at RO +689.5 sec. The total impulse used was

approximately 300 lb-sec, all from module 1. Module 2 engines did not fire as a result of LOX blowdown.

At RO +689.5 sec, pitch, yaw and roll maneuvers were initiated and were as follows:

Pitch: Command pitch attitude to local horizontal

Yaw: Command yaw attitude to hold a zero yaw angle of attack

Roll: Command roll attitude to +75 deg (clockwise looking forward).

The impulse consumption required to accomplish the roll maneuver was 73.5 lb-sec (table 19-2). Miscellaneous limit cycling used 1,037 lb-sec impulse from modules 1 and 2, respectively.

TABLE 25-1
VEHICLE CHARACTERISTICS USED IN FLIGHT SIMULATION
FROM R0 +592 TO R0 +597 SEC

DESCRIPTION	REFERENCE	VALUES	
		AT BURNOUT	POST SEPARATION
Centers of gravity (in.)	X (Gimbal location, sta 100)	834.5	413.8
	Y (Positive toward fin plane IV)	-10.0	-4.8
	Z (Positive toward fin plane I)	4.0	3.3
Moments of inertia (slug-ft^2)	I_{xx}	104,700	101,000
	I_{yy}	3,079,000	555,000
	I_{zz}	3,079,000	557,000
Mass (lbm)		80,000	34,700

TABLE 25-2
IMPULSE USAGE FROM R0 +592 TO R0 +597 SEC

ENGINE	IMPULSE USAGE (lbf-sec)		
	FROM FLIGHT	SIMULATION	
		NOMINAL VENT	NON-NOMINAL VENT
I_p	126	79	112
III_p	0	0	0
III_{IV}	0	0	8
I_{II}	453	480	488
III_{II}	443	458	435
I_{IV}	0	0	0
Module 1	579	559	580
Module 2	443	458	443

TABLE 25-3
APS IMPULSE USAGE

ENGINE	S-IVB/CSM SEPARATION TO R0 +610 SEC (lbf-sec)		R0 +610 TO R0 +650 SEC (lbf-sec)	
	FROM FLIGHT	FLIGHT SIMULATION	FROM FLIGHT	FLIGHT SIMULATION
I_p	138	94	177	255
III_p	0	0	3,323	3,154
III_{IV}	153	30	1,887	1,942
I_{II}	175	112	69	195
III_{II}	126	86	112	296
I_{IV}	202	38	2,211	2,314
Module 1	-	-	2,457	2,764
Module 2	-	-	5,322	5,392

TABLE 25-4
MAXIMUM S-IVB/IU ANGULAR DEVIATIONS DUE TO
SERVICE PROPULSION SYSTEM ENGINE PLUME IMPINGEMENT

COORDINATE		MAXIMUM DEVIATION (θ-χ deg)	
		FROM FLIGHT	FROM SIMULATION
Pitch	nose up	3.45	3.0
	nose down	61.9	51.9
Yaw	nose right	2.28	3.1
	nose left	29.2	24.4
Roll	clockwise	0.0	0.0
	counterclockwise	23.5	27.6

Note: χ = Commanded Euler angles
θ = Vehicle Euler angles

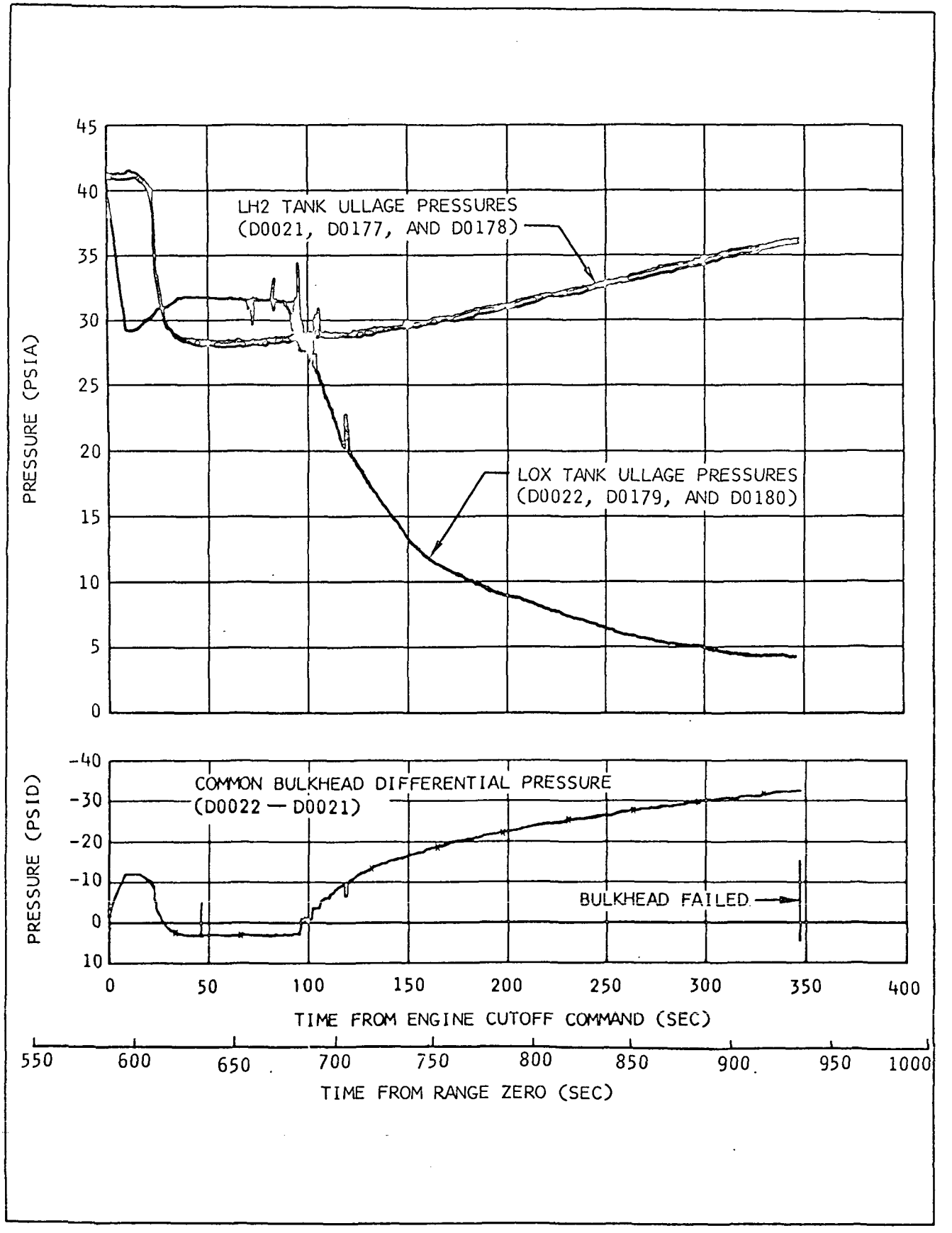


Figure 25-1. LOX and LH2 Tank Ullage and Common Bulkhead Differential Pressure

24 October 1966

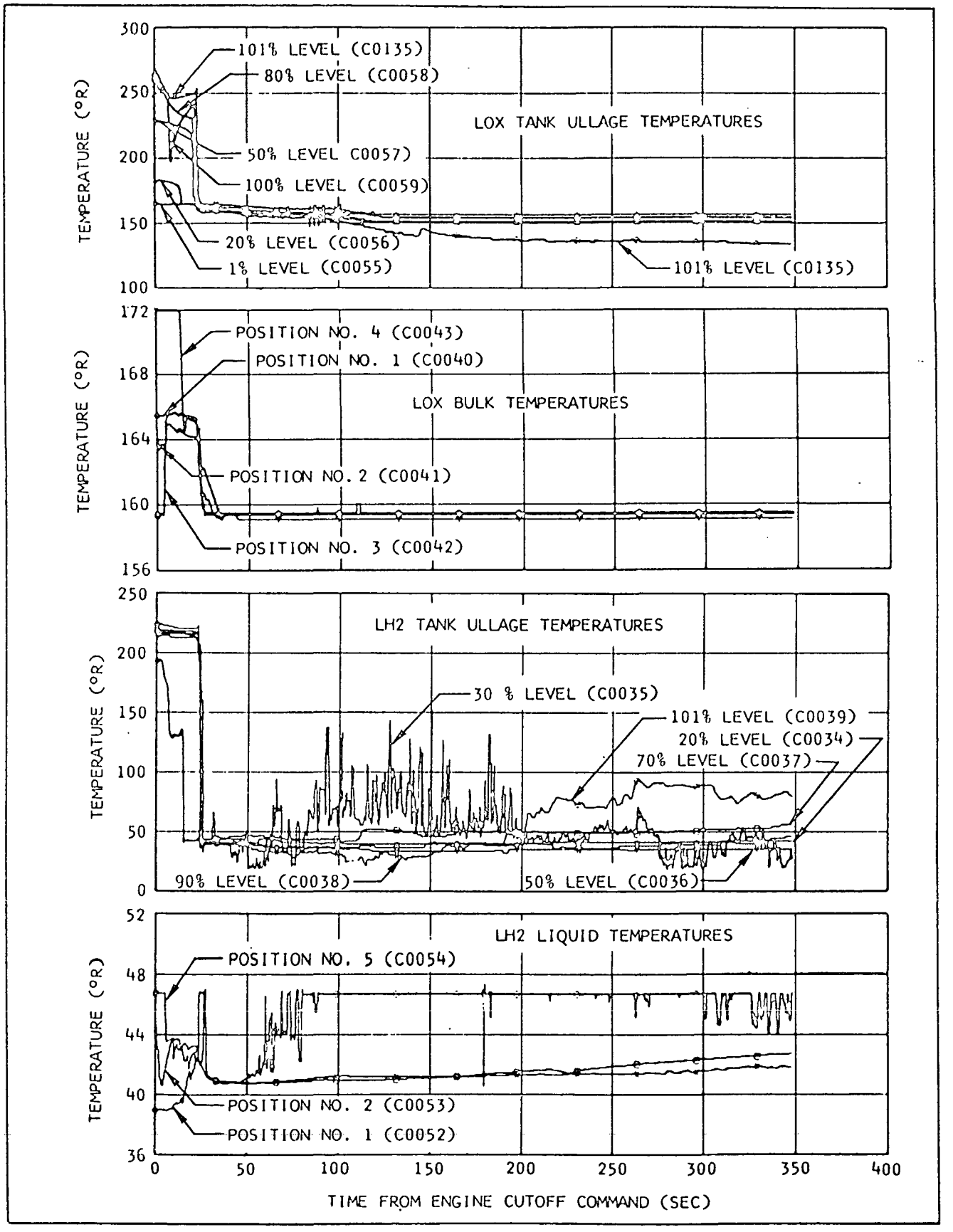


Figure 25-2. LOX and LH2 Tank Temperature

24 October 1966

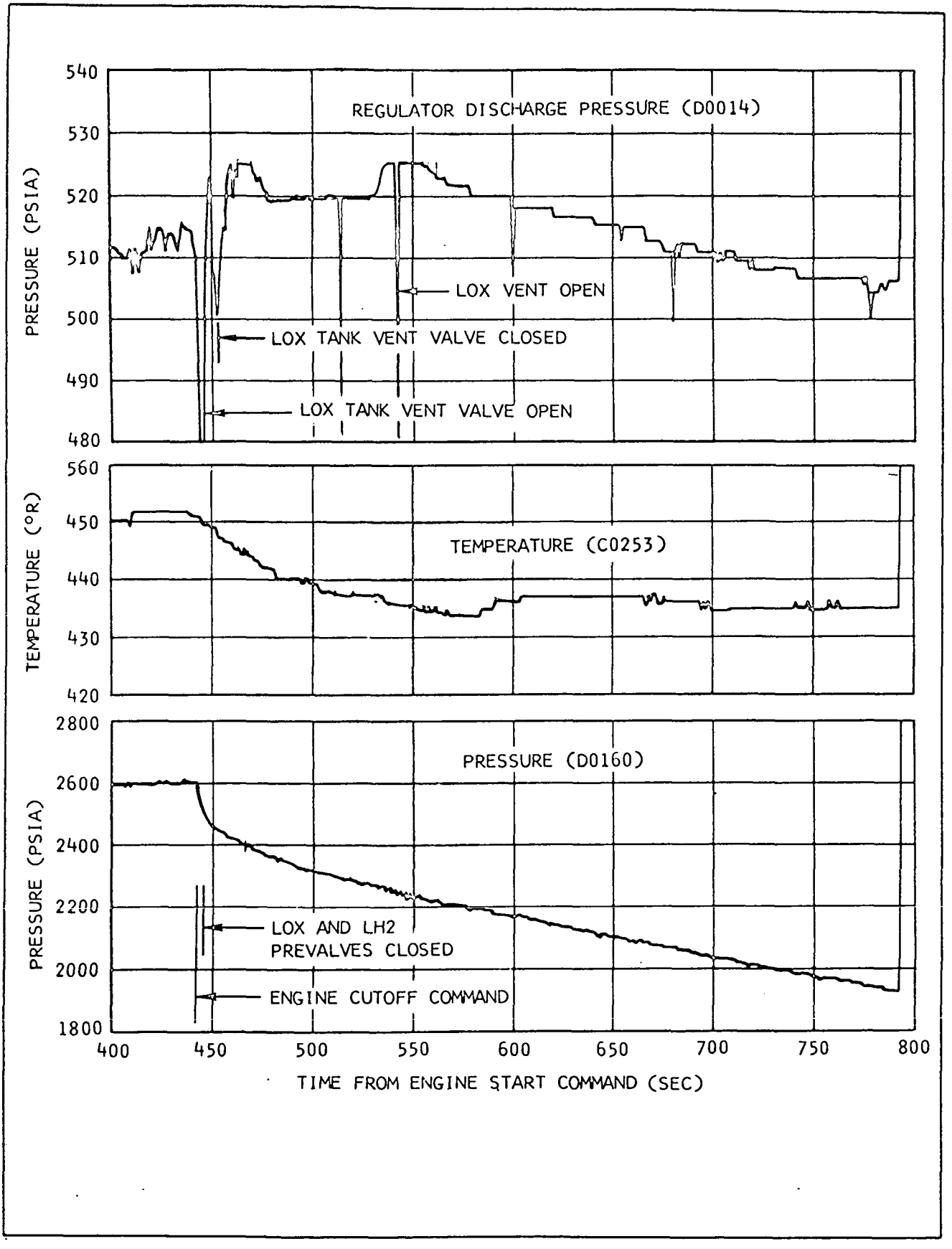


Figure 25-3. Pneumatic Control Sphere Conditions During Coast

24 October 1966

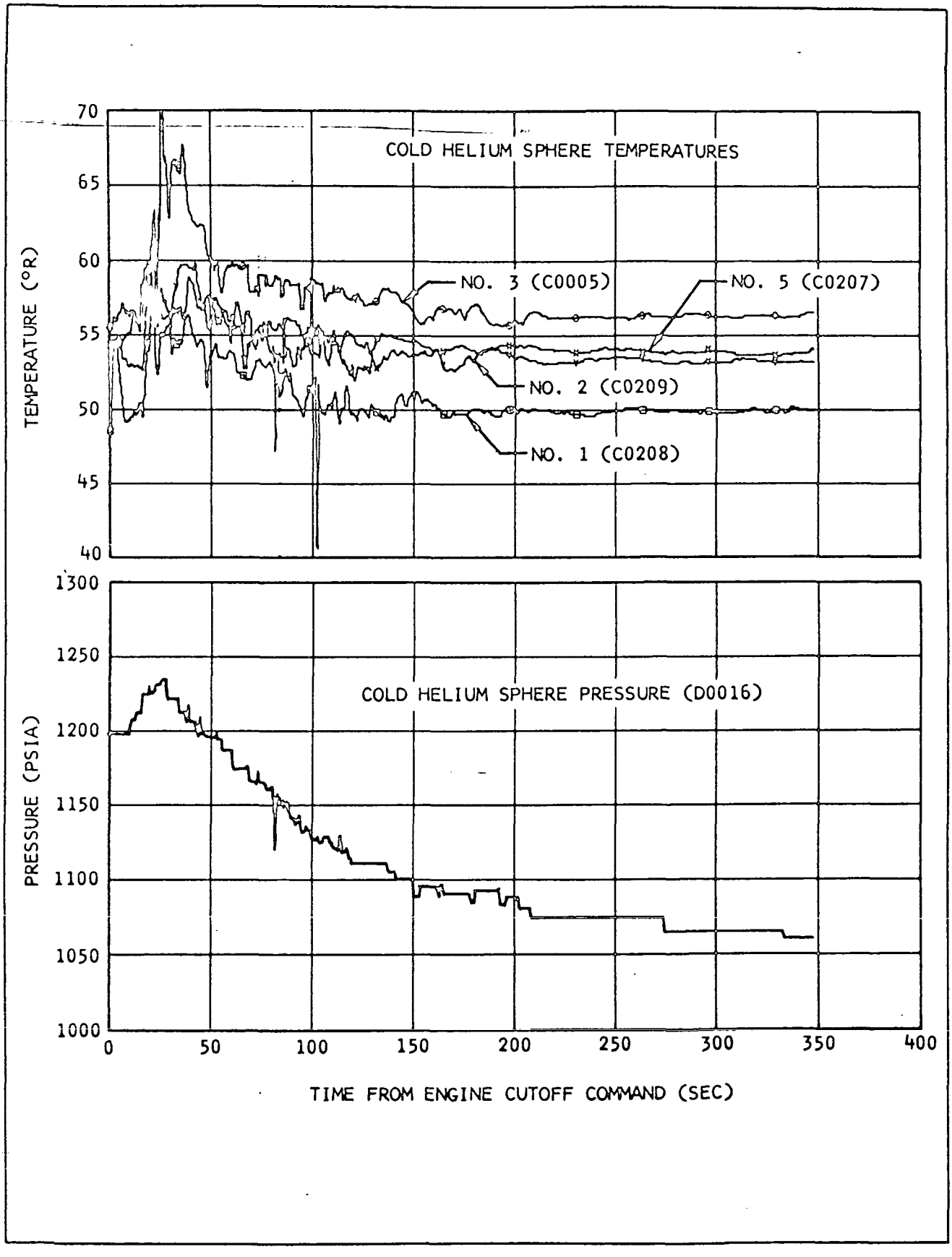
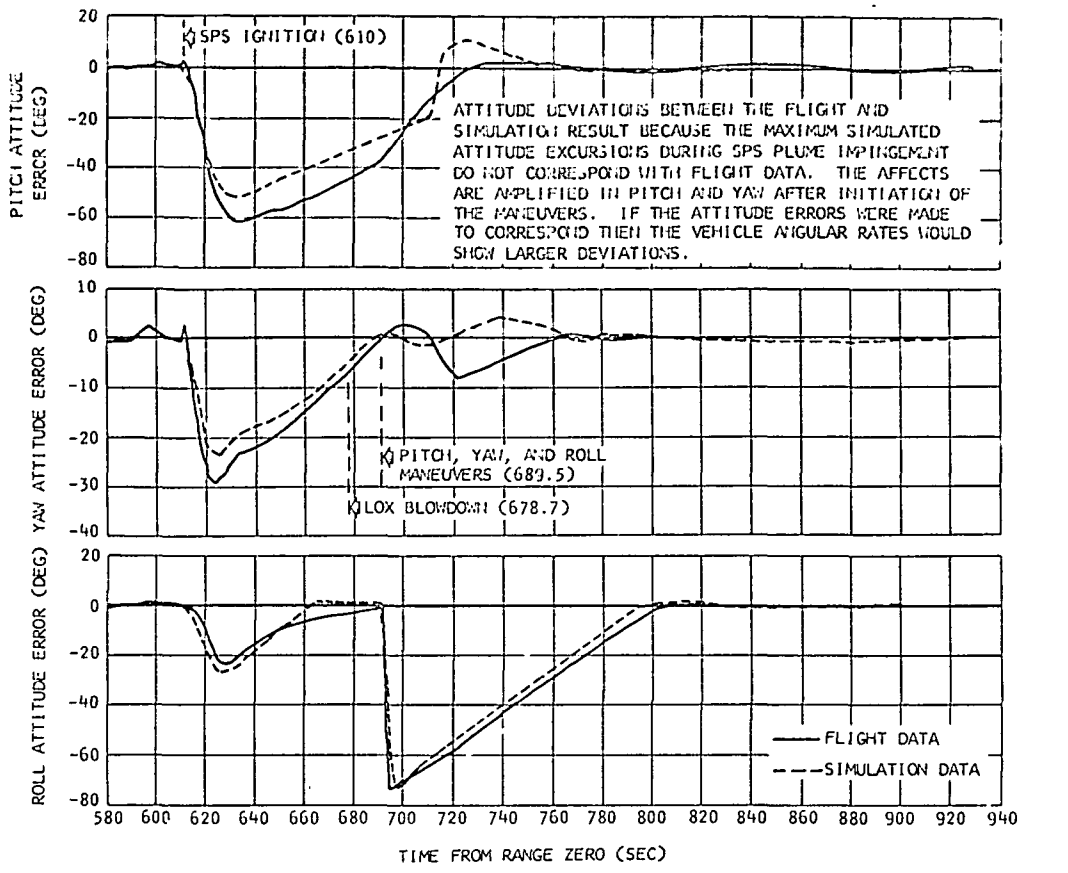


Figure 25-4. Cold Helium Sphere Conditions During Coast

24 October 1966



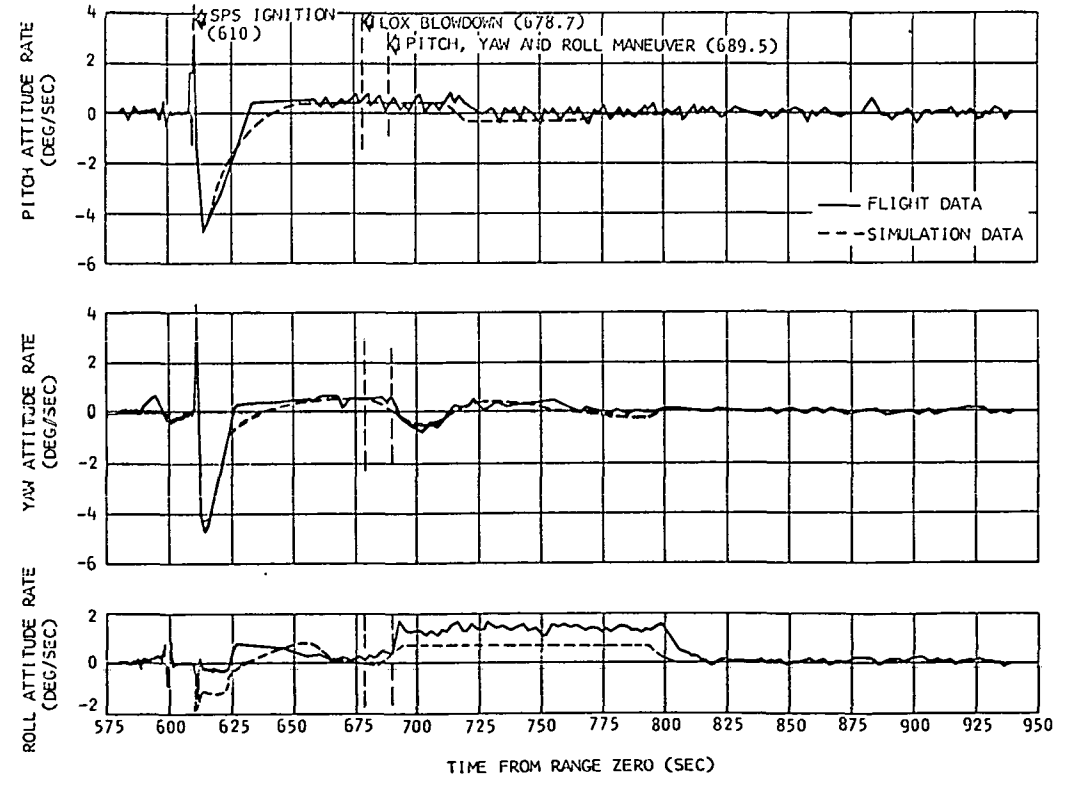


Figure 25-5. Attitude Errors and Rates Following S-IVB Cutoff

24 October 1966

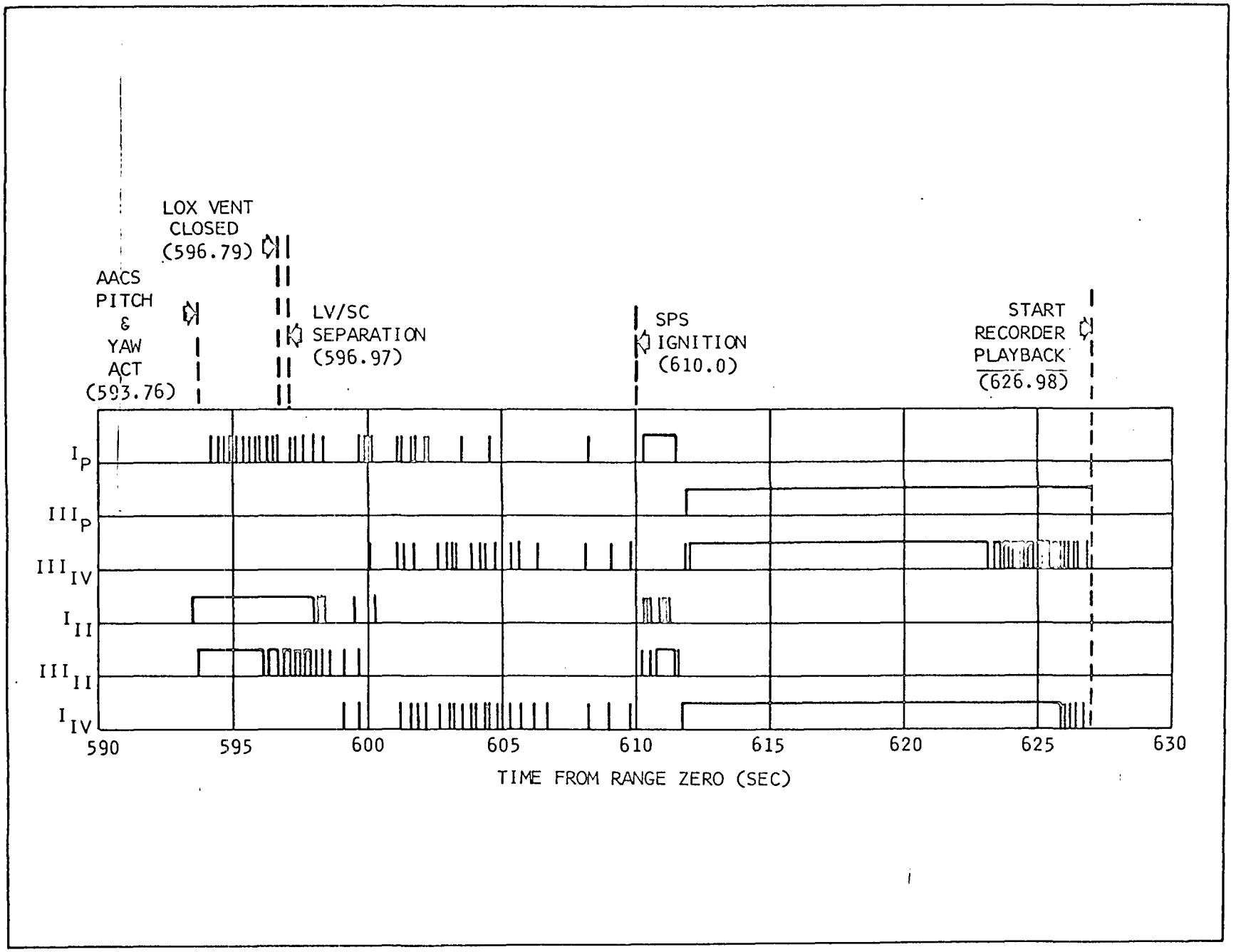


Figure 25-6. Auxiliary Propulsion System Firing History Following S-IVB Cutoff (Sheet 1 of 3)

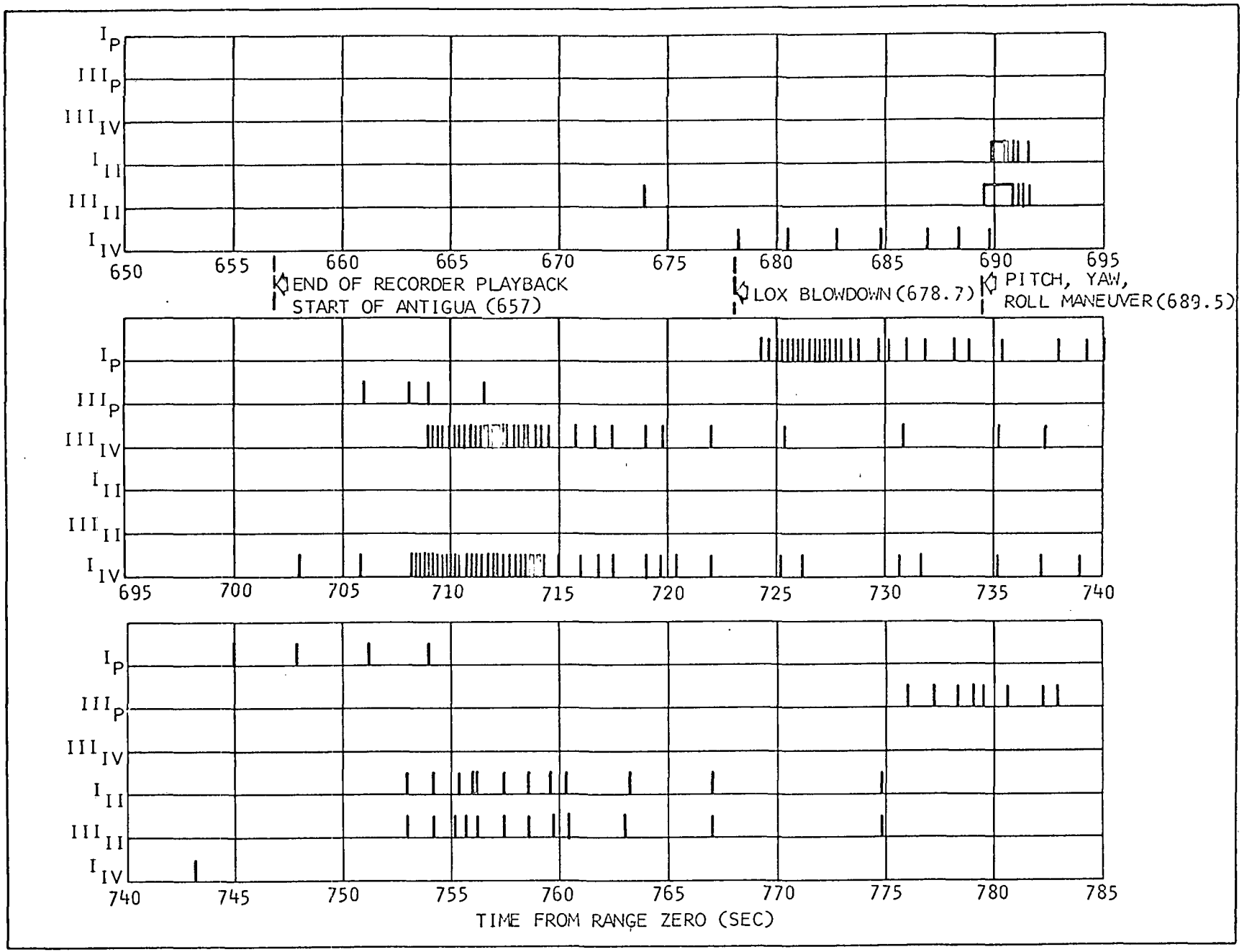


Figure 25-6. Auxiliary Propulsion System Firing History (RO +655 sec to RO +941 sec) (Sheet 2 of 3)

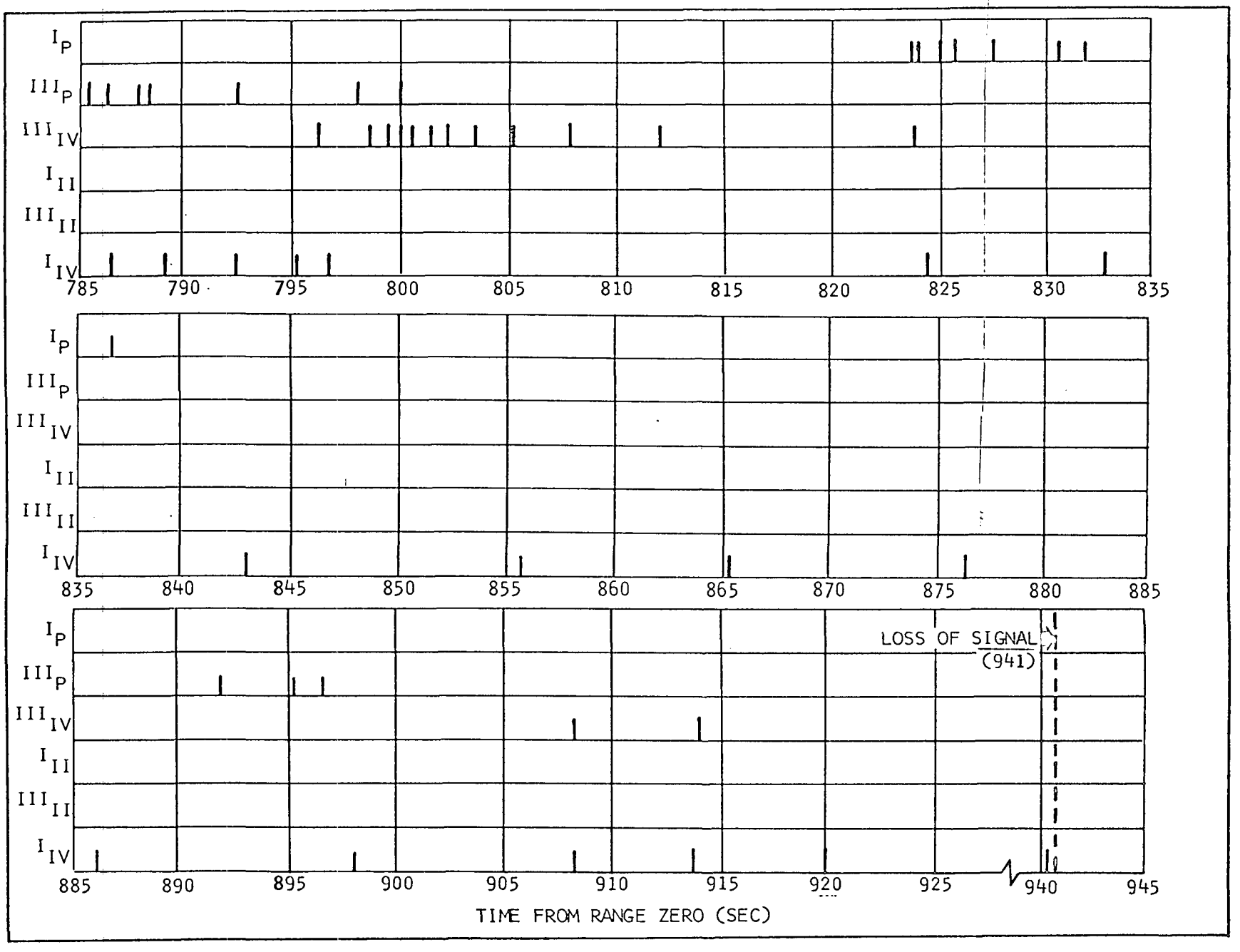


Figure 25-6. Auxiliary Propulsion System Firing History Following S-IVB Cutoff (Sheet 3 of 3)

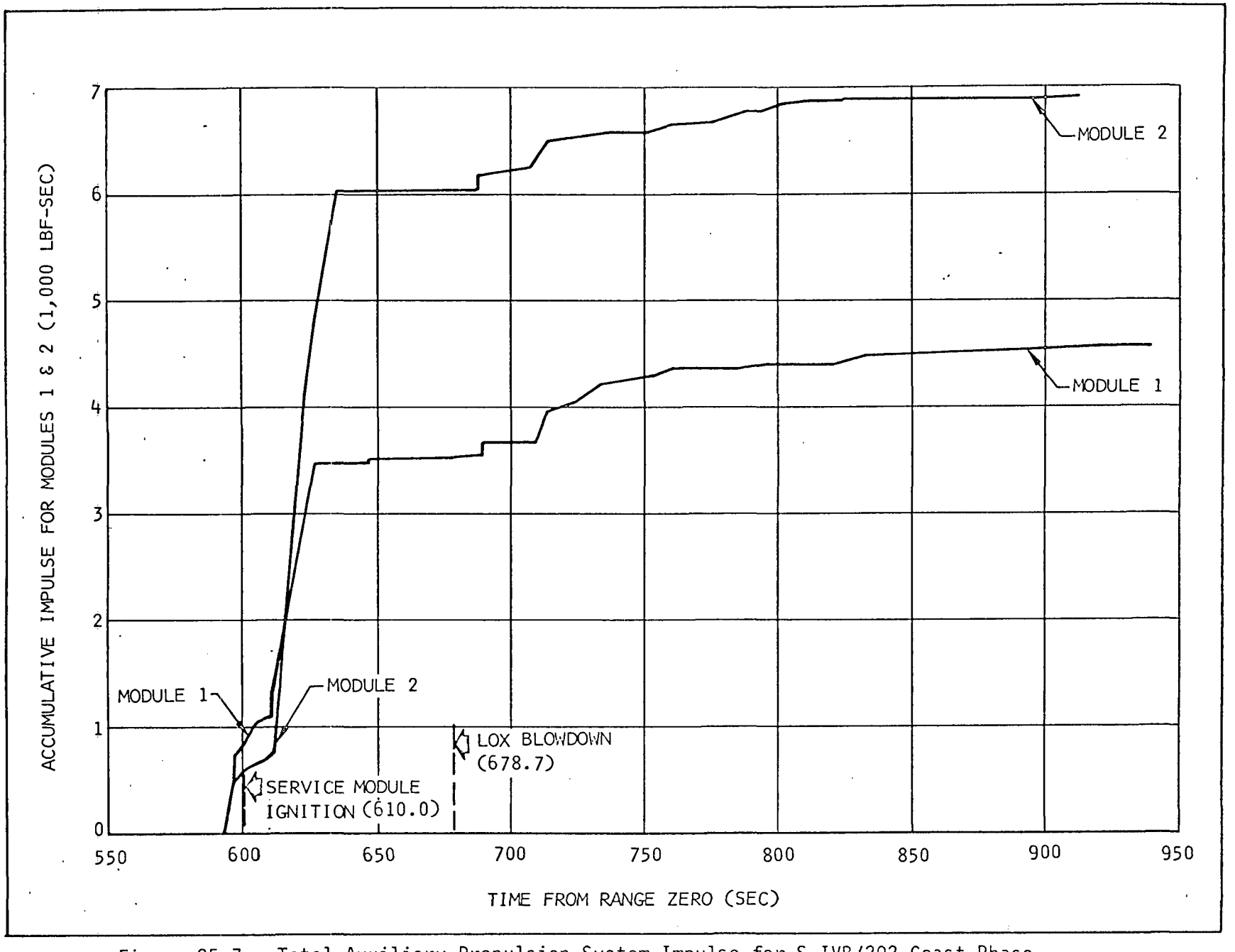


Figure 25-7. Total Auxiliary Propulsion System Impulse for S-IVB/202 Coast Phase

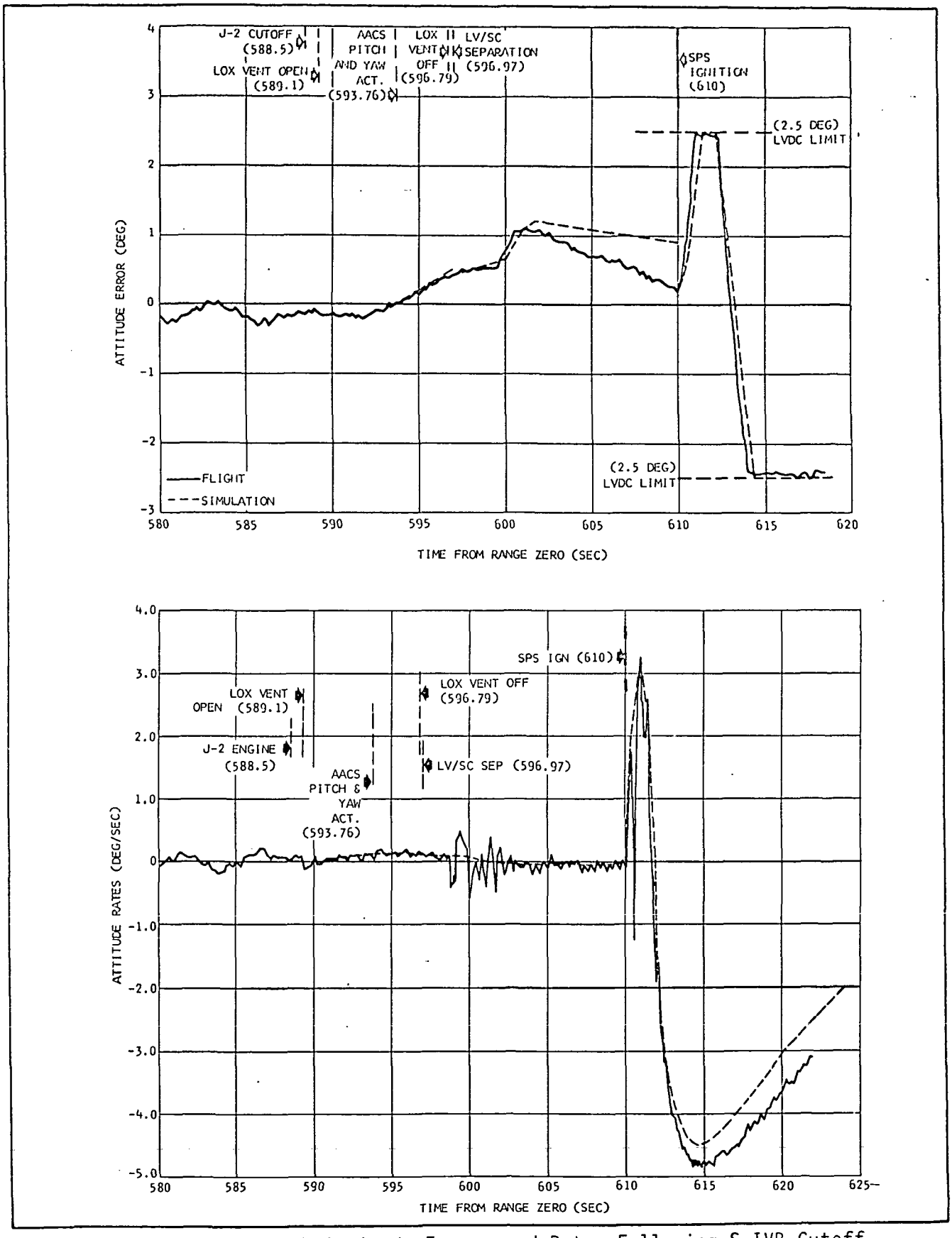


Figure 25-8. Pitch Attitude Errors and Rates Following S-IVB Cutoff

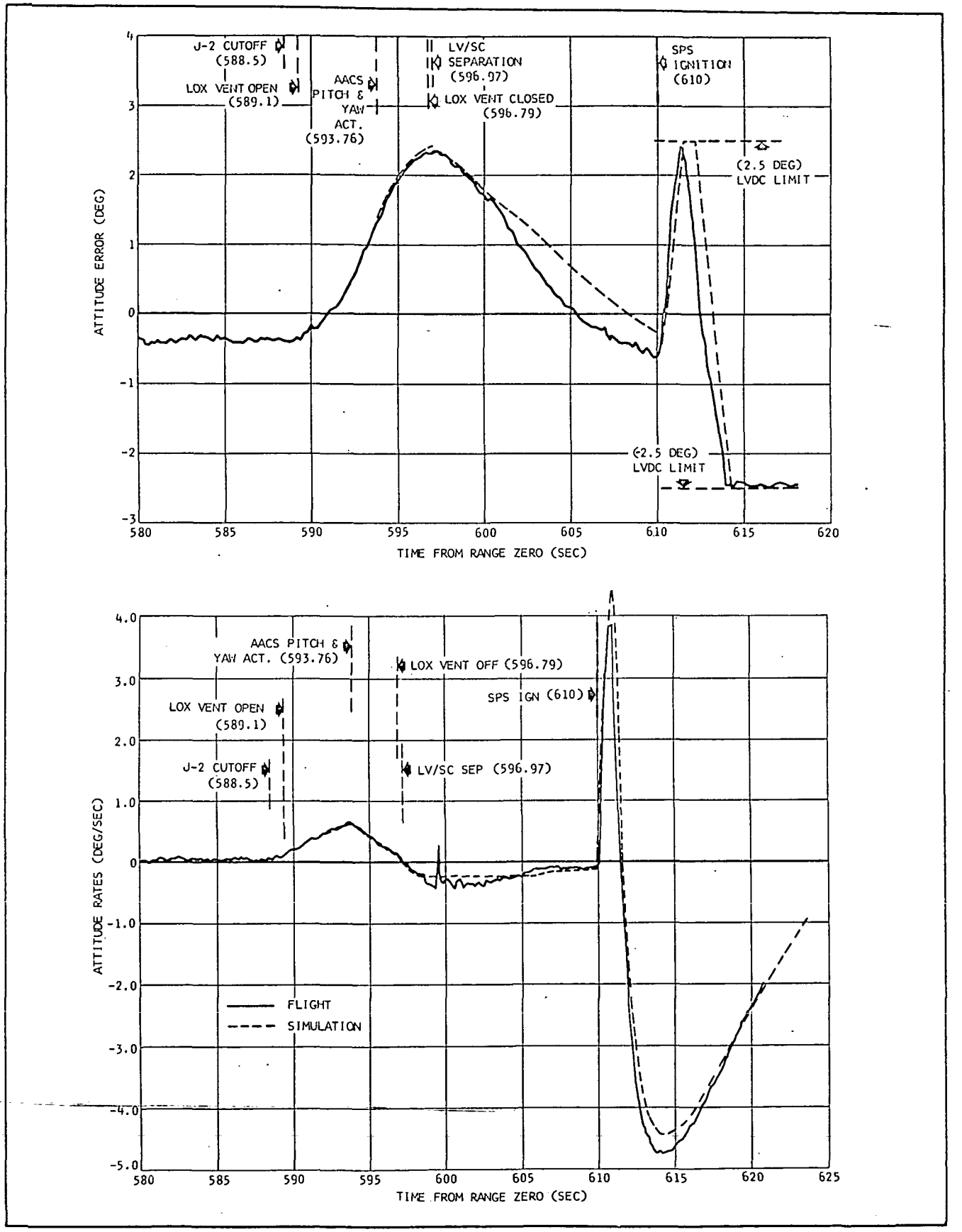


Figure 25-9. Yaw Attitude Errors and Rates Following S-IVB Cutoff

24 October 1966

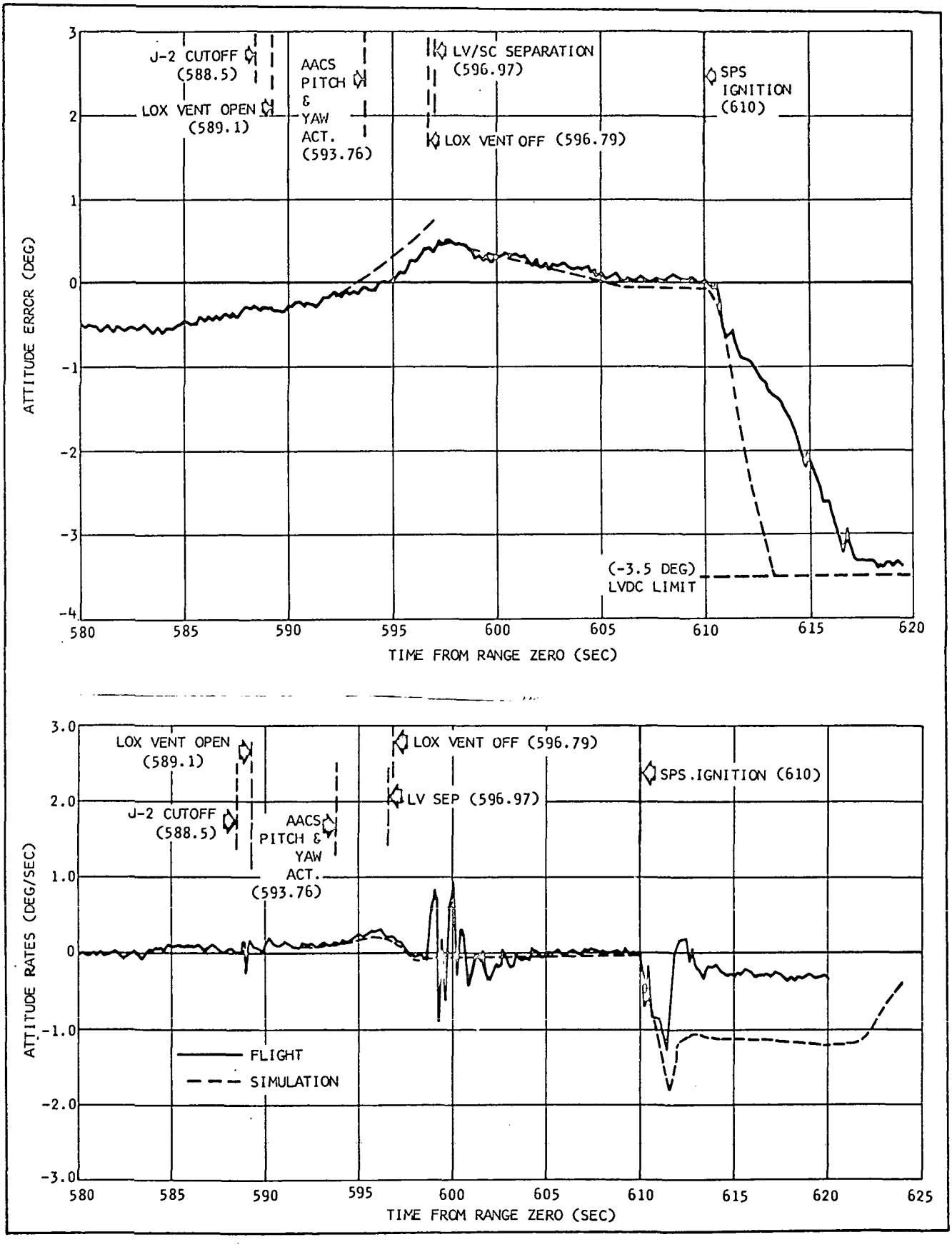
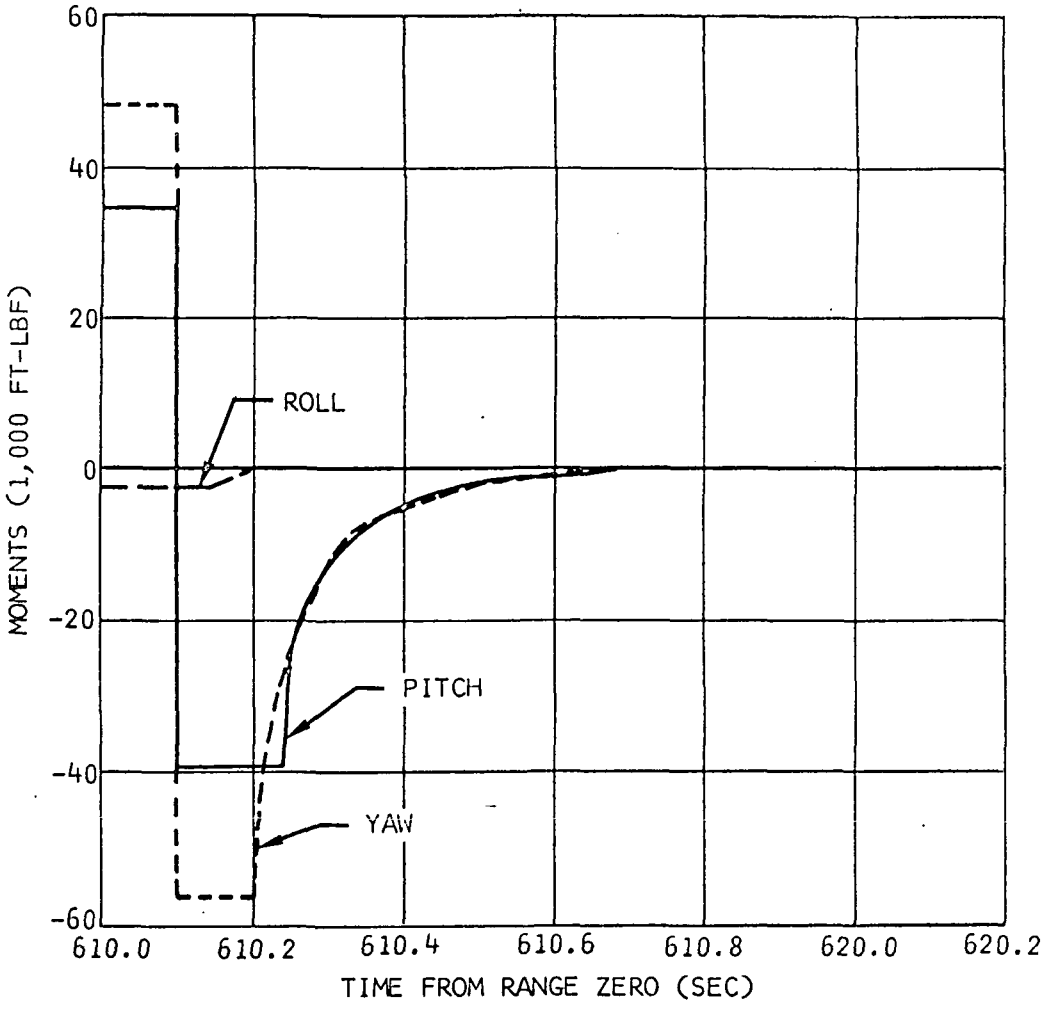


Figure 25-10. Roll Attitude Errors and Rates Following S-IVB Cutoff

24 October 1966



NOTE: + CAUSES MOMENT NOSE UP, NOSE RIGHT, CLOCKWISE ROLL

Figure 25-11. Estimated SC Engine Plume Impingement Disturbance on S-IVB-202 During Orbital Coast

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1. MASS CHARACTERISTICS DATA

This appendix presents a mass summary, a mass characteristics breakdown, and mass characteristics summary (tables AP 1-1, 1-2, and 1-3), as calculated by the WS11 computer program for the AS-202 second flight stage (S-IVB stage, IU, nose cone and LH2 payload).

Table AP 1-4 defines the terms and abbreviations used in printouts.

The mass summary (table AP 1-1) is an itemized listing of the mass of major components (including all propellants, gases, etc.).

The mass characteristics breakdown (table AP 1-2) is an itemized listing of all components giving mass, center of gravity and moment of inertia for the indicated time.

The mass characteristics summary (table AP 1-3), is a time listing of the AS-202 second flight stage mass characteristics, and includes total stage products of inertia.

All mass characteristics parameters are time referenced to AS-202 vehicle range zero and progress chronologically from S-IVB end of thrust decay to loss of telemetry signal.

Figure AP 1-1 shows the coordinates used in calculating mass characteristics.

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TABLE AP 1-1 (Sheet 1 of 2)
DEFINITIONS FOR MASS CHARACTERISTICS
COMPUTER PROGRAM WS11

TERM	DEFINITIONS	UNITS
Time	Time is referenced to range time. All computing was done in the pounds, inches, and pound inches squared system of units. (Items below the TOTAL REMAINING line were converted to other unit systems.) Pound mass is defined as 1/32.174 slugs.	Seconds
DAC Station	Distance along the H axis from the arbitrary S-IVB stage reference zero. The ZERO station is located so that the S-IVB stage engine gimbal point is station 100.0. Positive values increase in the forward direction and negative values are aft of station zero.	Inches
H Arm	Distance along the centerline of the S-IVB stage from the center of gravity of the item under consideration to S-IVB stage DAC station zero.	Inches
L Arm	Distance from the center of gravity of the item under consideration to the centerline of the S-IVB stage along an axis perpendicular to the centerline and coinciding with position II and IV. Position II is negative and position IV is positive.	Inches
V Arm	Distance from the center of gravity of item under consideration to the centerline of the stage along an axis perpendicular to the H and L axes and coinciding with positions I and III. Position I is negative and position II is positive.	Inches
Pound Inches Square	Moment of inertia about the center of gravity of each item or total of items	$Lbm\text{-}in^2$
Roll MOI	Moment of inertia of any item of total, about an axis through its own center of gravity and parallel to the H axis.	$Lbm\text{-}in^2$

TABLE AP 1-1 (Sheet 2 of 2)
DEFINITIONS FOR MASS CHARACTERISTICS
COMPUTER PROGRAM WS11

TERM	DEFINITIONS	UNITS
Pitch MOI	Moment of inertia of any item or total about an axis through its own center of gravity and parallel to the V axis.	$Lb\text{-}in^2$
Yaw MOI	Moment of inertia of any item or total, about an axis through its own center of gravity and parallel to the L axis.	$Lb\text{-}in^2$
Items Remaining	A listing of all items being considered at the current computing time that will be considered at the next computing time.	None
Total Remaining	A summation of the above	None
Items Jettisoned	A listing of all items being considered at the current computing time that will not be considered at the next computing time.	None
Total Jettisoned	A summation of the items being jettisoned at the current computing time.	None
KGM	Kilograms	
SLG	Slugs	
VS	Vehicle station (when center of gravity is expressed in coordinates other than S-IVB stage).	Inches
GS	Center of gravity expressed in terms of distance from engine gimbal point of the stage being considered.	Inches
SS	Center of Gravity expressed in terms of stage coordinates when individual items are in another coordinate system.	Inches
SLF	Slug feed squared.	
KM^2	Kilogram meters squared.	

TABLE AP 1-2 (Sheet 1 of 10)
MASS BREAKDOWN SUMMARY

LIFTOFF — TIME 0.930 — ITEMS REMAINING

SEQ	DESCRIPTION	MASS (POUNDS)	STATION (INCHES) H. ARM	STATION (INCHES) L.ARM	STATION (INCHES) V.ARM	MOI (POUND INCHES SQUARE) ROLL	MOI (POUND INCHES SQUARE) PITCH	MOI (POUND INCHES SQUARE) YAW
1.	AFT FRAME	25.00	300.70	0.0	0.0	.42055224 04	.29735208 06	.29735208 06
2.	DETONATION PKG	3.00	291.00	0.0	0.0	.65000000 05	.46599836 05	.46599836 05
3.	FROST	50.00	429.40	0.0	0.0	.84617466 06	.72163448 06	.72334448 06
7.	ULLAGE PKT GRN	174.10	225.80	0.0	0.0	.35463811 07	.17471502 07	.17471502 07
8.	ULLAGE PKT CSE	222.30	221.80	0.4	-0.7	.40754614 07	.20372789 07	.20372789 07
9.	LAUNCH ESCAPE	8411.00	1512.00	0.0	-0.1	.25712308 07	.99603454 08	.99603454 08
21.	SLA RING	91.00	1747.70	0.0	-1.8	.54150273 06	.24615865 06	.24615865 06
22.	COMMAND MODULE	12761.00	1251.00	0.1	5.2	.26326249 08	.22728087 08	.22503284 08
23.	SERVICE MODULE	9865.00	1124.30	0.8	-1.3	.29584513 08	.47581183 08	.44478875 08
24.	S/M PROPELLANT	22483.00	1124.40	27.2	-11.4	.35114433 08	.62252378 08	.66584222 08
31.	ADAPTER	3725.00	856.00	1.1	-2.9	.43367974 08	.59668379 08	.59044265 08
32.	INSTRUMENT UNIT	4402.10	698.00	-1.1	-10.7	.48055180 08	.36840222 08	.33015233 08
33.	S4B203 PRY STG	23055.00	328.07	5.7	-2.0	.24756000 09	.10166287 10	.10139226 10
34.	LOX ULLAGE GAS	34.30	318.44	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
35.	LOX IN TANK	193190.00	241.85	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
36.	LOX IN PORTS	13.00	155.00	-25.0	13.0	.18720000 04	.29250000 04	.32500000 04
37.	LOX IN LINES	246.00	134.80	4.4	-9.9	.22718616 05	.22718616 05	.22718616 05
38.	LOX IN ENGINE	188.00	71.00	0.0	0.0	.13549182 06	.50253674 05	.50253674 05
39.	LOX HELO VALVE	0.00	71.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
40.	LH2 ULLAGE GAS	189.00	617.51	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
41.	LH2 IN TANK	37014.00	434.08	0.0	0.0	.00000000 00	.11919582 09	.11919582 09
42.	LH2 IN LINES	38.00	187.01	-50.0	-66.8	.44993827 05	.48951516 05	.48951516 05
43.	LH2 IN ENGINE	15.00	71.00	0.0	0.0	.13282574 06	.55790440 04	.55790440 04
44.	LH2 HELO VALVE	0.00	71.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
45.	COLD HE QUAD 1	172.00	404.30	86.3	-75.6	.00000000 00	.15812001 05	.15812001 05
46.	COLD HE QUAD 2	172.00	404.30	113.8	20.0	.00000000 00	.15812001 05	.15812001 05
47.	APS PROP FD 1	44.00	268.00	0.0	-140.0	.00000000 00	.92160000 04	.92160000 04
48.	APS PROP FD 2	44.00	268.00	0.0	140.0	.00000000 00	.92160000 04	.92160000 04
49.	APS HELIUM	3.00	268.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
50.	HYDRAULIC OIL	14.50	110.00	-4.2	6.7	.83520000 04	.32625000 04	.32625000 04
51.	N2 HYD RESERV	1.80	135.80	-37.2	10.7	.00000000 00	.00000000 00	.00000000 00
52.	AIR HYD PUMP	2.50	130.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
53.	HE ENG PNEU	2.55	88.40	-22.6	14.6	.00000000 00	.00000000 00	.00000000 00
54.	HE VEH PNEU	1.00	144.60	41.0	17.5	.00000000 00	.00000000 00	.00000000 00
55.	GH2-START TANK	5.00	88.40	-22.6	14.6	.00000000 00	.00000000 00	.00000000 00
56.	ENV CONT FLUID	43.00	642.70	0.0	0.0	.66114865 04	.33749023 06	.33749023 06
	TOTAL REMAINING	318147.04	448.49	2.5	-1.3	.50965867 08	.43371940 11	.43377648 11
						SLF .10936155 06	SLF .93613812 07	SLF .93625013 07

S-1/S-IVB SEPARATION — TIME 144.270 — ITEMS JETTISONED

SEQ	DESCRIPTION	MASS (POUNDS)	STATION (INCHES) H. ARM	STATION (INCHES) L.ARM	STATION (INCHES) V.ARM	MOI (POUND INCHES SQUARE) ROLL	MOI (POUND INCHES SQUARE) PITCH	MOI (POUND INCHES SQUARE) YAW
1.	AFT FRAME	25.00	300.70	0.0	0.0	.42055224 04	.29735208 06	.29735208 06
2.	DETONATION PKG	3.00	291.00	0.0	0.0	.65000000 05	.46599836 05	.46599836 05
3.	FROST	0.00	429.40	0.0	0.0	.11657202 01	.96561373 00	.96561373 00
	TOTAL JETTISONED	28.00	300.74	0.0	0.0	.68644336 06	.34395636 06	.34395636 06
						SLF .10439828 03	SLF .74239565 02	SLF .74239565 02

S-1/S-IVB SEPARATION — TIME 144.270 — ITEMS REMAINING

SEQ	DESCRIPTION	MASS (POUNDS)	STATION (INCHES) H. ARM	STATION (INCHES) L.ARM	STATION (INCHES) V.ARM	MOI (POUND INCHES SQUARE) ROLL	MOI (POUND INCHES SQUARE) PITCH	MOI (POUND INCHES SQUARE) YAW
7.	ULLAGE PKT GRN	171.93	225.80	0.0	0.0	.36414114 07	.17448316 07	.17448316 07
8.	ULLAGE PKT CSE	222.30	221.80	0.4	-0.7	.40754614 07	.20372789 07	.20372789 07
9.	LAUNCH ESCAPE	8411.00	1512.00	0.0	-0.1	.25712308 07	.99603454 08	.99603454 08
21.	SLA RING	91.00	1747.70	0.0	-1.8	.54150273 06	.24615865 06	.24615865 06
22.	COMMAND MODULE	12761.00	1251.00	0.1	5.2	.26326249 08	.22728087 08	.22503284 08
23.	SERVICE MODULE	9865.00	1124.30	0.8	-1.3	.29584513 08	.47581183 08	.44478875 08
24.	S/M PROPELLANT	22483.00	1124.40	27.2	-11.4	.35114433 08	.62252378 08	.66584222 08
31.	ADAPTER	3725.00	856.00	1.1	-2.9	.43367974 08	.59668379 08	.59044265 08
32.	INSTRUMENT UNIT	4402.10	698.00	-1.1	-10.7	.48055180 08	.36840222 08	.33015233 08
33.	S4B203 PRY STG	23055.00	328.07	5.7	-2.0	.24756000 09	.10166287 10	.10139226 10
34.	LOX ULLAGE GAS	34.30	318.44	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
35.	LOX IN TANK	193190.00	241.85	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
36.	LOX IN PORTS	13.00	155.00	-25.0	13.0	.18720000 04	.29250000 04	.32500000 04
37.	LOX IN LINES	246.00	134.80	4.4	-9.9	.22718616 05	.22718616 05	.22718616 05
38.	LOX IN ENGINE	188.00	71.00	0.0	0.0	.13549182 06	.50253674 05	.50253674 05
39.	LOX HELO VALVE	0.00	71.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
40.	LH2 ULLAGE GAS	189.00	617.51	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
41.	LH2 IN TANK	37014.00	434.08	0.0	0.0	.00000000 00	.11919582 09	.11919582 09
42.	LH2 IN LINES	38.00	187.01	-50.0	-66.8	.44993827 05	.48951516 05	.48951516 05
43.	LH2 IN ENGINE	15.00	71.00	0.0	0.0	.13282574 06	.55790440 04	.55790440 04
44.	LH2 HELO VALVE	0.00	71.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
45.	COLD HE QUAD 1	172.00	404.30	86.3	-75.6	.00000000 00	.15812001 05	.15812001 05
46.	COLD HE QUAD 2	172.00	404.30	113.8	20.0	.00000000 00	.15812001 05	.15812001 05
47.	APS PROP FD 1	44.00	268.00	0.0	-140.0	.00000000 00	.92160000 04	.92160000 04
48.	APS PROP FD 2	44.00	268.00	0.0	140.0	.00000000 00	.92160000 04	.92160000 04
49.	APS HELIUM	3.00	268.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
50.	HYDRAULIC OIL	14.50	110.00	-4.2	6.7	.83520000 04	.32625000 04	.32625000 04
51.	N2 HYD RESERV	1.80	135.80	-37.2	10.7	.00000000 00	.00000000 00	.00000000 00
52.	AIR HYD PUMP	2.50	130.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
53.	HE ENG PNEU	2.55	88.40	-22.6	14.6	.00000000 00	.00000000 00	.00000000 00
54.	HE VEH PNEU	1.00	144.60	41.0	17.5	.00000000 00	.00000000 00	.00000000 00
55.	GH2-START TANK	5.00	88.40	-22.6	14.6	.00000000 00	.00000000 00	.00000000 00
56.	ENV CONT FLUID	43.00	642.70	0.0	0.0	.66114865 04	.33749023 06	.33749023 06
	TOTAL REMAINING	318063.07	448.51	2.5	-1.3	.50854116 08	.43368720 11	.43374317 11
						SLF .10955563 06	SLF .93607052 07	SLF .93618156 07

TABLE AP 1-2 (Sheet 2 of 10)
MASS BREAKDOWN SUMMARY

S-IVB ENGINE START COMMAND — TIME 145.624 — ITEMS REMAINING

SEQ	DESCRIPTION	MASS (POUNDS)	STATION (INCHES) H. ARM	L.ARM	V.ARM	MOI (POUND INCHES SQUARE) ROLL	PITCH	YAW
7.	ULLAGE PKT GRN	109.18	225.80	0.0	0.0	.21991361 07	.11089386 07	.11089386 07
8.	ULLAGE PKT CSE	222.30	221.80	0.4	-0.7	.40754614 07	.20372089 07	.20372089 07
9.	LAUNCH ESCAPE	9611.00	1512.00	0.0	-0.1	.25712309 07	.99603456 08	.99603456 08
21.	SLA RING	91.00	1047.70	0.0	-1.8	.54159273 06	.24615865 06	.24615865 06
22.	COMMAND MODULE	12061.00	1251.00	0.1	5.2	.26326249 08	.22728087 08	.20592256 08
23.	SERVICE MODULE	9845.00	1124.30	0.8	-1.3	.29586512 08	.47581183 08	.46478875 08
24.	S/M PROPELLANT	22483.00	1124.40	27.2	-11.4	.35114633 08	.62252378 08	.66584222 08
31.	ADAPTER	3725.00	856.00	1.1	-2.9	.43357976 08	.59608379 08	.59044265 08
32.	INSTRUMNT UNIT	4497.10	698.90	-1.1	-10.7	.68055189 08	.36840222 08	.32915233 08
33.	S4B2C2 DRY STG	23055.00	328.07	5.7	-2.3	.26766999 09	.10166287 10	.10138226 10
34.	LOX ULLAGE GAS	36.39	317.44	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
35.	LOX IN TANK	193139.00	241.85	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
36.	LOX IN PORTS	13.00	155.00	-25.0	10.0	.18720000 04	.29250000 04	.32500000 04
37.	LOX IN LINES	246.00	136.80	6.4	-9.9	.22718616 05	.22718616 05	.22718616 05
38.	LOX IN ENGINE	108.00	71.00	0.0	0.0	.13049182 06	.60253674 05	.60253674 05
39.	LOX RELD VALVE	0.00	71.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
40.	LH2 ULLAGE GAS	189.60	617.51	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
41.	LH2 IN TANK	37016.00	434.98	0.0	0.0	.00000000 00	.11919582 09	.11919582 09
42.	LH2 IN LINES	38.00	187.91	-59.9	-64.8	.44993827 05	.48051516 05	.48051516 05
43.	LH2 IN ENGINE	10.00	71.00	0.0	0.0	.12082576 05	.55790439 04	.55790439 04
44.	LH2 RELD VALVE	0.00	71.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
45.	COLD HE QUAD 1	172.00	494.30	86.3	-75.6	.00000000 00	.15812001 06	.15812001 06
46.	COLD HE QUAD 2	172.00	494.30	113.8	20.0	.00000000 00	.15812001 06	.15812001 06
47.	APS PROP FD 1	63.86	248.00	0.0	-140.0	.00000000 00	.91959241 04	.91959241 04
48.	APS PROP FD 2	63.86	248.00	0.0	140.0	.00000000 00	.91959241 04	.91959241 04
49.	APS HELIUM	3.00	248.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
50.	HYDRAULIC OIL	14.50	110.00	-4.2	6.0	.83520000 04	.32625000 04	.32625000 04
51.	N2 HYD RESERV	1.80	135.80	-37.2	10.7	.00000000 00	.00000000 00	.00000000 00
52.	AIR HYD PUMP	0.50	130.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
53.	HE ENG PNEU	2.55	88.40	-22.0	14.6	.00000000 00	.00000000 00	.00000000 00
54.	HE VEH PNEU	1.00	164.60	61.0	17.5	.00000000 00	.00000000 00	.00000000 00
55.	GH2-START TANK	5.00	88.40	-22.4	14.6	.00000000 00	.00000000 00	.00000000 00
56.	ENV CONT FLUID	43.00	662.70	0.0	0.0	.66116800 06	.33049923 06	.33049923 06
	TOTAL REMAINING	316000.94	448.55	2.5	-1.0	.50677194 09	.43364944 11	.43370567 11
						SLF .10938169 06	SLF .93598925 07	SLF .93611641 07

S-IVB 90 PERCENT THRUST — TIME 149.126 — ITEMS REMAINING

SEQ	DESCRIPTION	MASS (POUNDS)	STATION (INCHES) H. ARM	L.ARM	V.ARM	MOI (POUND INCHES SQUARE) ROLL	PITCH	YAW
7.	ULLAGE PKT GRN	-0.00	225.80	0.0	0.0	-.99860558 00	-.50327727 00	-.50327727 00
8.	ULLAGE PKT CSE	222.30	221.80	0.4	-0.7	.40754614 07	.20372089 07	.20372089 07
9.	LAUNCH ESCAPE	9611.00	1512.00	0.0	-0.1	.25712309 07	.99603456 08	.99603456 08
21.	SLA RING	91.00	1047.70	0.0	-1.8	.54159273 06	.24615865 06	.24615865 06
22.	COMMAND MODULE	12061.00	1251.00	0.1	5.2	.26326249 08	.22728087 08	.20592256 08
23.	SERVICE MODULE	9845.00	1124.30	0.8	-1.3	.29586512 08	.47581183 08	.46478875 08
24.	S/M PROPELLANT	22483.00	1124.40	27.2	-11.4	.35114633 08	.62252378 08	.66584222 08
31.	ADAPTER	3725.00	856.00	1.1	-2.9	.43357976 08	.59608379 08	.59044265 08
32.	INSTRUMNT UNIT	4497.10	698.90	-1.1	-10.7	.68055189 08	.36840222 08	.32915233 08
33.	S4B2C2 DRY STG	23055.00	328.07	5.7	-2.3	.26766999 09	.10166287 10	.10138226 10
34.	LOX ULLAGE GAS	36.69	317.96	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
35.	LOX IN TANK	192567.53	241.66	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
36.	LOX IN PORTS	13.00	155.00	-25.0	10.0	.18720000 04	.29250000 04	.32500000 04
37.	LOX IN LINES	246.00	136.80	6.4	-9.9	.22718616 05	.22718616 05	.22718616 05
38.	LOX IN ENGINE	108.00	71.00	0.0	0.0	.13049182 06	.60253674 05	.60253674 05
39.	LOX RELD VALVE	30.00	71.00	0.0	0.0	.36247733 05	.16737134 05	.16737134 05
40.	LH2 ULLAGE GAS	190.68	616.80	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
41.	LH2 IN TANK	36870.77	434.43	0.0	0.0	.00000000 00	.11696447 09	.11696447 09
42.	LH2 IN LINES	38.00	187.91	-59.9	-64.8	.44993827 05	.48051516 05	.48051516 05
43.	LH2 IN ENGINE	10.00	71.00	0.0	0.0	.12082576 05	.55790439 04	.55790439 04
44.	LH2 RELD VALVE	10.00	71.00	0.0	0.0	.12082578 05	.55790448 04	.55790448 04
45.	COLD HE QUAD 1	171.40	494.30	86.3	-75.6	.00000000 00	.15756423 06	.15756423 06
46.	COLD HE QUAD 2	171.40	494.30	113.8	20.0	.00000000 00	.15756423 06	.15756423 06
47.	APS PROP FD 1	63.50	248.00	0.0	-140.0	.00000000 00	.91440001 04	.91440001 04
48.	APS PROP FD 2	63.50	248.00	0.0	140.0	.00000000 00	.91440001 04	.91440001 04
49.	APS HELIUM	3.00	248.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
50.	HYDRAULIC OIL	14.50	110.00	-4.2	6.0	.83520000 04	.32625000 04	.32625000 04
51.	N2 HYD RESERV	1.80	135.80	-37.2	10.7	.00000000 00	.00000000 00	.00000000 00
52.	AIR HYD PUMP	0.50	130.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
53.	HE ENG PNEU	2.55	88.40	-22.0	14.6	.00000000 00	.00000000 00	.00000000 00
54.	HE VEH PNEU	1.00	164.60	61.0	17.5	.00000000 00	.00000000 00	.00000000 00
55.	GH2-START TANK	5.00	88.40	-22.4	14.6	.00000000 00	.00000000 00	.00000000 00
56.	ENV CONT FLUID	43.00	662.70	0.0	0.0	.66116800 06	.33049923 06	.33049923 06
	TOTAL REMAINING	315242.20	448.77	2.5	-1.0	.50458285 09	.43354104 11	.43359717 11
						SLF .10890920 06	SLF .93575528 07	SLF .93587643 07

TABLE AP 1-2 (Sheet 3 of 10)
MASS BREAKDOWN SUMMARY

S-IVB PROPELLANT UTILIZATION ACTIVE — TIME 151.620 — ITEMS REMAINING

SEQ	DESCRIPTION	MASS (POUNDS)	STATION (INCHES) H. ARM	L.ARM	V.ARM	MOI (POUND INCHES SQUARE) ROLL	PITCH	YAW
7.	ULLAGE PKT GRN	-0.00	225.80	0.0	0.0	-.99840558 09	-.50327727 00	-.50327727 00
8.	ULLAGE PKT RSE	222.30	221.80	0.4	-0.7	.40754614 07	.20372089 07	.20372089 07
9.	LAUNCH ESCAPE	8411.00	1512.30	0.0	-0.1	.25712308 07	.99633456 08	.99633456 08
21.	SLA RING	91.00	1947.70	0.0	-1.8	.56150273 04	.24615865 06	.24615865 06
22.	COMMAND MODULE	12041.00	1251.00	0.1	5.2	.26334249 08	.22728087 08	.22502254 08
23.	SERVICE MODULE	9845.00	1124.30	0.0	-1.3	.29586512 08	.47581183 08	.44478875 08
24.	S/M PROPELLANT	72483.00	1124.40	27.2	-11.4	.35114433 08	.62252378 08	.61584222 08
31.	ADAPTER	3725.00	856.00	1.1	-2.0	.43357974 08	.59068379 08	.58044245 08
32.	INSTRUMNT UNIT	6402.10	698.00	-1.1	-10.7	.68855189 08	.36840222 08	.32915233 08
33.	S4B2D2 DRY STG	23055.00	328.07	5.7	-2.0	.26754099 09	.10166287 10	.10139236 10
34.	LOX ULLAGE GAS	38.60	317.10	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
35.	LOX IN TANK	191450.85	241.33	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
36.	LOX IN PORTS	13.00	155.00	-25.0	10.0	.18722005 04	.29250030 04	.32500033 04
37.	LOX IN LINES	944.00	136.80	6.4	-9.9	.22718616 05	.22718616 05	.22718616 05
38.	LOX IN ENGINE	198.00	71.00	0.0	0.0	.13069182 06	.60253674 05	.60253674 05
39.	LOX RELD VALVE	30.00	71.00	0.0	0.0	.36247727 05	.16737132 05	.16737132 05
40.	LH2 ULLAGE GAS	191.87	615.83	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
41.	LH2 IN TANK	36671.33	433.66	0.0	0.0	.00000000 00	.11393099 09	.11393099 09
42.	LH2 IN LINES	38.00	197.91	-59.9	-64.6	.44993827 05	.48851516 05	.48851516 05
43.	LH2 IN ENGINE	10.00	71.00	0.0	0.0	.12682574 05	.55790439 04	.55790439 04
44.	LH2 RELD VALVE	10.00	71.00	0.0	0.0	.12682574 05	.55790439 04	.55790439 04
45.	COLD HE QUAD 1	177.04	494.30	96.3	-75.6	.00000000 00	.15716842 06	.15716842 06
46.	COLD HE QUAD 2	177.04	494.30	113.8	-20.0	.00000000 00	.15716842 06	.15716842 06
47.	APS PROP FD 1	63.45	248.00	0.0	-140.0	.00000000 00	.91369219 04	.91369219 04
48.	APS PROP FD 2	63.45	248.00	0.0	140.0	.00000000 00	.91373023 04	.91373023 04
49.	APS HELIUM	3.00	248.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
50.	HYDRAULIC OIL	14.50	110.00	-4.2	6.0	.83520000 04	.32625000 04	.32625000 04
51.	N2 HYD RESERV	1.00	135.80	-37.2	10.7	.00000000 00	.00000000 00	.00000000 00
52.	AIR HYD PUMP	9.50	130.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
53.	HE ENG PNEU	2.55	98.40	-22.0	14.6	.00000000 00	.00000000 00	.00000000 00
54.	HE VEH PNEU	1.00	144.60	61.0	17.5	.00000000 00	.00000000 00	.00000000 00
55.	GH2-START TANK	1.00	98.40	-22.4	14.6	.00000000 00	.00000000 00	.00000000 00
56.	ENV CONT FLUID	43.00	442.70	0.0	0.0	.66116803 06	.33049923 06	.33049923 06
	TOTAL REMAINING	314129.07	449.00	2.5	-1.0	.50464278 09	.43338618 11	.43344222 11
						SLF .13890487 06	SLF .93542103 07	SLF .93554200 07

SUMMARY PRINTOUT — TIME 156.222 — ITEMS JETTISONED

SEQ	DESCRIPTION	MASS (POUNDS)	STATION (INCHES) H. ARM	L.ARM	V.ARM	MOI (POUND INCHES SQUARE) ROLL	PITCH	YAW
7.	ULLAGE PKT GRN	-0.00	225.80	0.0	0.0	-.99840558 09	-.50327727 00	-.50327727 00
8.	ULLAGE PKT RSE	222.30	221.80	0.4	-0.7	.40754614 07	.20372089 07	.20372089 07
	TOTAL JETTISONED	222.30	221.80	0.4	-0.7	.40754604 07	.20372084 07	.20372084 07
						SLF .87954765 03	SLF .43971120 03	SLF .43971120 03

SUMMARY PRINTOUT — TIME 156.222 — ITEMS REMAINING

SEQ	DESCRIPTION	MASS (POUNDS)	STATION (INCHES) H. ARM	L.ARM	V.ARM	MOI (POUND INCHES SQUARE) ROLL	PITCH	YAW
9.	LAUNCH ESCAPE	8411.00	1512.30	0.0	-0.1	.25712308 07	.99633456 08	.99633456 08
21.	SLA RING	91.00	1947.70	0.0	-1.8	.56150273 04	.24615865 06	.24615865 06
22.	COMMAND MODULE	12041.00	1251.00	0.1	5.2	.26334249 08	.22728087 08	.22502254 08
23.	SERVICE MODULE	9845.00	1124.30	0.0	-1.3	.29586512 08	.47581183 08	.44478875 08
24.	S/M PROPELLANT	72483.00	1124.40	27.2	-11.4	.35114433 08	.62252378 08	.61584222 08
31.	ADAPTER	3725.00	856.00	1.1	-2.0	.43357974 08	.59068379 08	.58044245 08
32.	INSTRUMNT UNIT	6402.10	698.00	-1.1	-10.7	.68855189 08	.36840222 08	.32915233 08
33.	S4B2D2 DRY STG	23055.00	328.07	5.7	-2.0	.26754099 09	.10166287 10	.10139236 10
34.	LOX ULLAGE GAS	41.00	315.60	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
35.	LOX IN TANK	189498.17	240.44	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
36.	LOX IN PORTS	13.00	155.00	-25.0	10.0	.18722005 04	.29250030 04	.32500033 04
37.	LOX IN LINES	944.00	136.80	6.4	-9.9	.22718616 05	.22718616 05	.22718616 05
38.	LOX IN ENGINE	198.00	71.00	0.0	0.0	.13069182 06	.60253674 05	.60253674 05
39.	LOX RELD VALVE	30.00	71.00	0.0	0.0	.36247727 05	.16737132 05	.16737132 05
40.	LH2 ULLAGE GAS	104.07	414.03	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
41.	LH2 IN TANK	36205.32	432.22	0.0	0.0	.00000000 00	.10829770 09	.10829770 09
42.	LH2 IN LINES	38.00	197.91	-59.9	-64.6	.44993827 05	.48851516 05	.48851516 05
43.	LH2 IN ENGINE	10.00	71.00	0.0	0.0	.12682574 05	.55790439 04	.55790439 04
44.	LH2 RELD VALVE	10.00	71.00	0.0	0.0	.12682574 05	.55790439 04	.55790439 04
45.	COLD HE QUAD 1	177.17	494.30	96.3	-75.6	.00000000 00	.15643807 06	.15643807 06
46.	COLD HE QUAD 2	177.17	494.30	113.8	20.0	.00000000 00	.15643807 06	.15643807 06
47.	APS PROP FD 1	63.36	248.00	0.0	-140.0	.00000000 00	.91239416 04	.91239416 04
48.	APS PROP FD 2	63.36	248.00	0.0	140.0	.00000000 00	.91242420 04	.91242420 04
49.	APS HELIUM	3.00	248.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
50.	HYDRAULIC OIL	14.50	110.00	-4.2	6.0	.83520000 04	.32625000 04	.32625000 04
51.	N2 HYD RESERV	1.00	135.80	-37.2	10.7	.00000000 00	.00000000 00	.00000000 00
52.	AIR HYD PUMP	9.50	130.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
53.	HE ENG PNEU	2.55	98.40	-22.0	14.6	.00000000 00	.00000000 00	.00000000 00
54.	HE VEH PNEU	1.00	144.60	61.0	17.5	.00000000 00	.00000000 00	.00000000 00
55.	GH2-START TANK	1.00	98.40	-22.4	14.6	.00000000 00	.00000000 00	.00000000 00
56.	ENV CONT FLUID	43.00	442.70	0.0	0.0	.66116803 06	.33049923 06	.33049923 06
	TOTAL REMAINING	311581.95	449.00	2.5	-1.0	.50044544 09	.43291051 11	.43295595 11
						SLF .13831619 06	SLF .93439326 07	SLF .93451378 07

TABLE AP 1-2 (Sheet 4 of 10)
MASS BREAKDOWN SUMMARY

SUMMARY PRINTOUT — TIME 168.930 — ITEMS JETTISONED

SEQ	DESCRIPTION	MASS (POUNDS)	STATION (INCHES) H. ARM	L.ARM	V.ARM	MOI (POUND INCHES SQUARE) ROLL	PITCH	YAW
9.	LAUNCH ESCAPE	8611.00	1512.90	0.0	-0.1	.25712308 07	.99603468 08	.99603468 08
	TOTAL JETTISONED	8611.00	1512.90	0.0	-0.1	.25712308 07	.99603468 08	.99603468 08
						SLF .55497463 03	SLF .21498527 05	SLF .21498527 05

SUMMARY PRINTOUT — TIME 168.930 — ITEMS REMAINING

SEQ	DESCRIPTION	MASS (POUNDS)	STATION (INCHES) H. ARM	L.ARM	V.ARM	MOI (POUND INCHES SQUARE) ROLL	PITCH	YAW
21.	SLA RING	91.00	1047.70	0.0	-1.8	.54150273 06	.24615845 06	.24615845 06
22.	COMMAND MODULE	12061.00	1751.00	0.1	5.2	.26326249 08	.22728087 08	.22728087 08
23.	SERVICE MODULE	9845.00	1124.30	0.0	-1.3	.29586512 08	.47581183 08	.44478875 08
24.	S/M PROPELLANT	22483.00	1124.40	27.2	-11.4	.35114433 08	.62252378 08	.64584227 08
31.	ADAPTER	3725.00	856.00	1.1	-2.9	.43347076 08	.59608379 08	.59044245 08
32.	INSTRUMNT UNIT	4402.10	698.90	-1.1	-10.7	.68005189 08	.36840222 08	.32015333 08
33.	S4B202 DRY STG	23055.00	328.07	5.7	-2.0	.26766999 09	.10166287 10	.10138334 10
34.	LOX ULLAGE GAS	51.56	311.12	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
35.	LOX IN TANK	186932.05	238.69	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
36.	LOX IN PORTS	13.00	155.00	-25.0	10.0	.18720000 04	.29250000 04	.32500000 04
37.	LOX IN LINES	246.00	134.80	6.4	-9.9	.22718616 05	.22718616 05	.22718616 05
38.	LOX IN ENGINE	108.00	71.00	0.0	0.0	.13069182 06	.60253674 05	.60253674 05
39.	LOX BELO VALVE	30.00	71.00	0.0	0.0	.36247727 05	.16737132 05	.16737132 05
40.	LH2 ULLAGE GAS	209.16	699.14	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
41.	LH2 IN TANK	35248.22	428.21	0.0	0.0	.00000000 00	.93098808 08	.93098808 08
42.	LH2 IN LINES	38.00	187.91	-59.0	-64.8	.44993827 05	.48951516 05	.48951516 05
43.	LH2 IN ENGINE	10.00	71.00	0.0	0.0	.12092576 05	.55790439 04	.55790439 04
44.	LH2 BELO VALVE	10.00	71.00	0.0	0.0	.12092576 05	.55790439 04	.55790439 04
45.	COLD HE QUAD 1	167.98	494.30	86.3	-75.6	.00000000 00	.15442126 06	.15442126 06
46.	COLD HE QUAD 2	167.98	494.30	113.8	20.0	.00000000 00	.15442126 06	.15442126 06
47.	APS PROP FD 1	63.11	248.00	0.0	-140.0	.00000000 00	.98877971 04	.98877971 04
48.	APS PROP FD 2	63.11	248.00	0.0	140.0	.00000000 00	.98881773 04	.98881773 04
49.	APS HELIUM	3.00	248.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
50.	HYDRAULIC OIL	14.50	110.00	-4.7	6.0	.83520000 04	.32625000 04	.32625000 04
51.	N2 HYD RESERV	1.80	135.80	-37.2	10.7	.00000000 00	.00000000 00	.00000000 00
52.	AIR HYD PUMP	0.50	130.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
53.	HE ENG PNEU	2.55	88.40	-22.0	14.6	.00000000 00	.00000000 00	.00000000 00
54.	HE VEH PNEU	1.00	164.60	61.0	17.5	.00000000 00	.00000000 00	.00000000 00
55.	GH2-START TANK	1.00	88.40	-22.4	14.6	.00000000 00	.00000000 00	.00000000 00
56.	ENV CONT FLUID	43.00	662.70	0.0	0.0	.66116800 06	.33049923 06	.33049923 06
	TOTAL REMAINING	299368.60	421.44	2.6	-1.1	.49749097 09	.33114718 11	.33120196 11
						SLF .10742165 06	SLF .71474839 07	SLF .71484455 07

SUMMARY PRINTOUT — TIME 200.000 — ITEMS REMAINING

SEQ	DESCRIPTION	MASS (POUNDS)	STATION (INCHES) H. ARM	L.ARM	V.ARM	MOI (POUND INCHES SQUARE) ROLL	PITCH	YAW
21.	SLA RING	91.00	1047.70	0.0	-1.8	.54150273 06	.24615865 06	.24615845 06
22.	COMMAND MODULE	12061.00	1751.00	0.1	5.2	.26326249 08	.22728087 08	.22750256 08
23.	SERVICE MODULE	9845.00	1124.30	0.0	-1.3	.29586512 08	.47581183 08	.44478875 08
24.	S/M PROPELLANT	22483.00	1124.40	27.2	-11.4	.35114433 08	.62252378 08	.64584227 08
31.	ADAPTER	3725.00	856.00	1.1	-2.9	.43347076 08	.59608379 08	.59044245 08
32.	INSTRUMNT UNIT	4402.10	698.90	-1.1	-10.7	.68005189 08	.36840222 08	.32015333 08
33.	S4B202 DRY STG	23055.00	328.07	5.7	-2.0	.26766999 09	.10166287 10	.10138334 10
34.	LOX ULLAGE GAS	75.19	303.91	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
35.	LOX IN TANK	170098.15	234.14	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
36.	LOX IN PORTS	13.00	155.00	-25.0	10.0	.18720000 04	.29250000 04	.32500000 04
37.	LOX IN LINES	246.00	134.80	6.4	-9.9	.22718616 05	.22718616 05	.22718616 05
38.	LOX IN ENGINE	108.00	71.00	0.0	0.0	.13069182 06	.60253674 05	.60253674 05
39.	LOX BELO VALVE	30.00	71.00	0.0	0.0	.36247727 05	.16737132 05	.16737132 05
40.	LH2 ULLAGE GAS	215.03	697.95	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
41.	LH2 IN TANK	32698.50	418.36	0.0	0.0	.00000000 00	.13990786 09	.13990786 09
42.	LH2 IN LINES	38.00	187.91	-59.0	-64.8	.44993827 05	.48951516 05	.48951516 05
43.	LH2 IN ENGINE	10.00	71.00	0.0	0.0	.12092576 05	.55790439 04	.55790439 04
44.	LH2 BELO VALVE	10.00	71.00	0.0	0.0	.12092576 05	.55790439 04	.55790439 04
45.	COLD HE QUAD 1	162.61	494.30	86.3	-75.6	.00000000 00	.14949033 06	.14949033 06
46.	COLD HE QUAD 2	162.61	494.30	113.8	20.0	.00000000 00	.14949033 06	.14949033 06
47.	APS PROP FD 1	62.50	248.00	0.0	-140.0	.00000000 00	.89996219 04	.89996219 04
48.	APS PROP FD 2	62.50	248.00	0.0	140.0	.00000000 00	.90000021 04	.90000021 04
49.	APS HELIUM	3.00	248.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
50.	HYDRAULIC OIL	14.50	110.00	-4.7	6.0	.83520000 04	.32625000 04	.32625000 04
51.	N2 HYD RESERV	1.80	135.80	-37.2	10.7	.00000000 00	.00000000 00	.00000000 00
52.	AIR HYD PUMP	0.50	130.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
53.	HE ENG PNEU	2.55	88.40	-22.0	14.6	.00000000 00	.00000000 00	.00000000 00
54.	HE VEH PNEU	1.00	164.60	61.0	17.5	.00000000 00	.00000000 00	.00000000 00
55.	GH2-START TANK	1.00	88.40	-22.4	14.6	.00000000 00	.00000000 00	.00000000 00
56.	ENV CONT FLUID	43.00	662.70	0.0	0.0	.66116800 06	.33049923 06	.33049923 06
	TOTAL REMAINING	279811.51	424.57	2.0	-1.2	.49738852 09	.32973917 11	.32979347 11
						SLF .10735437 06	SLF .71170925 07	SLF .71182439 07

TABLE AP 1-2 (Sheet 5 of 10)
MASS BREAKDOWN SUMMARY

SUMMARY PRINTOUT — TIME 300.000 — ITEMS REMAINING

SEQ	DESCRIPTION	MASS (POUNDS)	STATION (INCHES) H. ARM	L.ARM	V.ARM	MOI (POUND INCHES SQUARE) ROLL	PITCH	YAW
21.	SLA RING	91.00	1047.70	0.0	-1.8	.54150273 06	.24615865 06	.24615865 06
22.	COMMAND MODULE	12041.00	1251.00	0.1	5.2	.26324240 08	.22728087 08	.22592254 08
23.	SERVICE MODULE	9845.00	1124.30	0.0	-1.3	.29586512 08	.47581183 08	.44478876 08
24.	S/M PROPELLANT	22483.00	1124.40	27.2	-11.4	.35114633 08	.62252378 08	.66584222 08
31.	ADAPTER	3725.00	856.00	1.1	-2.9	.43347974 08	.59689379 08	.59044265 08
32.	INSTRUMNT UNIT	4492.10	698.00	-1.1	-10.7	.68035180 08	.36840222 08	.32915233 08
33.	S4B202 DRY STG	23055.00	328.07	5.7	-2.0	.26746999 09	.13166287 10	.13139224 10
34.	LOX ULLAGE GAS	151.21	284.30	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
35.	LOX IN TANK	125190.13	220.67	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
36.	LOX IN PORTS	13.00	155.00	-25.0	10.0	.18720000 04	.29250000 04	.32500000 04
37.	LOX IN LINES	246.00	136.80	6.4	-9.9	.22718616 05	.22718616 05	.22718616 05
38.	LOX IN ENGINE	108.00	71.00	0.0	0.0	.13049182 06	.60253674 05	.60253674 05
39.	LOX RELD VALVE	30.00	71.00	0.0	0.0	.36247727 05	.16737132 05	.16737132 05
40.	LH2 ULLAGE GAS	242.89	545.53	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
41.	LH2 IN TANK	26503.54	386.67	0.0	0.0	.00000000 00	.10461382 09	.10461382 09
42.	LH2 IN LINES	38.00	187.01	-59.0	-64.8	.44993827 05	.48051516 05	.48051516 05
43.	LH2 IN ENGINE	10.00	71.00	0.0	0.0	.12782576 05	.55790439 04	.55790439 04
44.	LH2 RELD VALVE	10.00	71.00	0.0	0.0	.12782576 05	.55790439 04	.55790439 04
45.	COLD HE QUAD 1	145.35	494.30	84.3	-75.6	.00000000 00	.12361996 06	.12361996 06
46.	COLD HE QUAD 2	145.35	494.30	113.8	20.0	.00000000 00	.13361996 06	.13361996 06
47.	APS PROP TP 1	62.20	248.00	0.0	-140.0	.00000000 00	.89703361 04	.89703361 04
48.	APS PROP TP 2	62.00	248.00	0.0	140.0	.00000000 00	.89406724 04	.89406724 04
49.	APS HELIUM	3.00	248.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
50.	HYDRAULIC OIL	14.50	110.00	-4.2	6.0	.83520000 04	.32625000 04	.32625000 04
51.	N2 HYD RESERV	1.80	135.80	-37.2	10.7	.00000000 00	.00000000 00	.00000000 00
52.	AIR HYD PUMP	0.50	130.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
53.	HE ENG PNEU	2.55	88.40	-22.0	14.6	.00000000 00	.00000000 00	.00000000 00
54.	HE VEH PNEU	1.00	144.60	41.0	17.5	.00000000 00	.00000000 00	.00000000 00
55.	GH2-START TANK	1.00	88.40	-22.4	14.6	.00000000 00	.00000000 00	.00000000 00
56.	ENV CONT FLUID	43.00	662.70	0.0	0.0	.66116800 06	.33049923 06	.33049923 06
	TOTAL REMAINING	226806.28	454.03	3.4	-1.4	.49634540 09	.31813724 11	.31818418 11
						SLF .10713123 06	SLF .68566764 07	SLF .68574805 07

SUMMARY PRINTOUT — TIME 400.000 — ITEMS REMAINING

SEQ	DESCRIPTION	MASS (POUNDS)	STATION (INCHES) H. ARM	L.ARM	V.ARM	MOI (POUND INCHES SQUARE) ROLL	PITCH	YAW
21.	SLA RING	91.00	1047.70	0.0	-1.8	.54150273 06	.24615865 06	.24615865 06
22.	COMMAND MODULE	12041.00	1251.00	0.1	5.2	.26324240 08	.22728087 08	.22592254 08
23.	SERVICE MODULE	9845.00	1124.30	0.0	-1.3	.29586512 08	.47581183 08	.44478876 08
24.	S/M PROPELLANT	22483.00	1124.40	27.2	-11.4	.35114633 08	.62252378 08	.66584222 08
31.	ADAPTER	3725.00	856.00	1.1	-2.9	.43347974 08	.59689379 08	.59044265 08
32.	INSTRUMNT UNIT	4492.10	698.00	-1.1	-10.7	.68035180 08	.36840222 08	.32915233 08
33.	S4B202 DRY STG	23055.00	328.07	5.7	-2.0	.26746999 09	.13166287 10	.13139224 10
34.	LOX ULLAGE GAS	227.23	269.84	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
35.	LOX IN TANK	80318.09	206.49	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
36.	LOX IN PORTS	13.00	155.00	-25.0	10.0	.18720000 04	.29250000 04	.32500000 04
37.	LOX IN LINES	246.00	136.80	6.4	-9.9	.22718616 05	.22718616 05	.22718616 05
38.	LOX IN ENGINE	108.00	71.00	0.0	0.0	.13049182 06	.60253674 05	.60253674 05
39.	LOX RELD VALVE	30.00	71.00	0.0	0.0	.36247727 05	.16737132 05	.16737132 05
40.	LH2 ULLAGE GAS	310.75	533.61	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
41.	LH2 IN TANK	16331.00	354.66	0.0	0.0	.00000000 00	.80891671 08	.80891671 08
42.	LH2 IN LINES	38.00	187.01	-59.0	-64.8	.44993827 05	.48051516 05	.48051516 05
43.	LH2 IN ENGINE	10.00	71.00	0.0	0.0	.12782576 05	.55790439 04	.55790439 04
44.	LH2 RELD VALVE	10.00	71.00	0.0	0.0	.12782576 05	.55790439 04	.55790439 04
45.	COLD HE QUAD 1	128.09	494.30	84.3	-75.6	.00000000 00	.11774958 06	.11774958 06
46.	COLD HE QUAD 2	128.09	494.30	113.8	20.0	.00000000 00	.11774958 06	.11774958 06
47.	APS PROP TP 1	62.00	248.00	0.0	-140.0	.00000000 00	.89046721 04	.89046721 04
48.	APS PROP TP 2	61.68	248.00	0.0	140.0	.00000000 00	.88813444 04	.88813444 04
49.	APS HELIUM	3.00	248.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
50.	HYDRAULIC OIL	14.50	110.00	-4.2	6.0	.83520000 04	.32625000 04	.32625000 04
51.	N2 HYD RESERV	1.80	135.80	-37.2	10.7	.00000000 00	.00000000 00	.00000000 00
52.	AIR HYD PUMP	0.50	130.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
53.	HE ENG PNEU	2.55	88.40	-22.0	14.6	.00000000 00	.00000000 00	.00000000 00
54.	HE VEH PNEU	1.00	144.60	41.0	17.5	.00000000 00	.00000000 00	.00000000 00
55.	GH2-START TANK	1.00	88.40	-22.4	14.6	.00000000 00	.00000000 00	.00000000 00
56.	ENV CONT FLUID	43.00	662.70	0.0	0.0	.66116800 06	.33049923 06	.33049923 06
	TOTAL REMAINING	173842.35	507.77	4.6	-1.9	.49405335 09	.29443225 11	.29447238 11
						SLF .10693077 06	SLF .63550278 07	SLF .63558508 07

24 October 1966

TABLE AP 1-2 (Sheet 6 of 10)
MASS BREAKDOWN SUMMARY

S-IVB ENGINE MIXTURE RATIO CUTBACK — TIME 475.720 — ITEMS REMAINING

SEQ	DESCRIPTION	MASS (POUNDS)	STATION (INCHES) R. ARM	L.ARM	V.ARM	MOI (POUND INCHES SQUARE) ROLL	PITCH	YAW
21.	SLA RING	91.00	1047.70	0.0	-1.8	.54150273 06	.24615865 06	.24615865 06
22.	COMMAND MODULE	12061.00	1251.00	0.1	5.2	.26326240 08	.27278087 08	.25592554 08
23.	SERVICE MODULE	9845.00	1124.30	0.8	-1.3	.29586512 08	.47581183 08	.44478875 08
24.	S/M PROPELLANT	22483.00	1124.40	27.2	-11.4	.35114633 08	.62252378 08	.66584272 08
31.	ADAPTER	3725.00	856.00	1.1	-2.9	.43367976 08	.59608379 08	.59044265 08
32.	INSTRUMNT UNIT	4492.10	698.00	-1.1	-10.7	.68055189 08	.36849222 08	.32015233 08
33.	S4B2D2 DRY STG	23055.00	328.07	5.7	-2.0	.26766999 09	.10166287 10	.10139224 10
34.	LOX ULLAGE GAS	302.54	256.57	0.0	0.0	.03000000 00	.00000000 00	.00000000 00
35.	LOX IN TANK	35526.74	188.72	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
36.	LOX IN PORTS	13.00	155.00	-25.0	13.0	.18722000 04	.29250000 04	.32500000 04
37.	LOX IN LINES	246.00	136.80	6.4	-9.9	.22718616 05	.22718616 05	.22718616 05
38.	LOX IN ENGINE	108.00	71.00	0.0	0.0	.13049182 06	.69253674 05	.69253674 05
39.	LOX BELO VALVE	39.00	71.00	0.0	0.0	.36247727 05	.16737132 05	.16737132 05
40.	LH2 ULLAGE GAS	373.40	501.34	0.0	0.0	.30000000 00	.00000000 00	.00000000 00
41.	LH2 IN TANK	8717.18	320.98	0.0	0.0	.00000000 00	.46806472 08	.46806472 08
42.	LH2 IN LINES	38.00	187.91	-58.9	-64.8	.44993827 05	.48051516 05	.48051516 05
43.	LH2 IN ENGINE	10.00	71.00	0.0	0.0	.12082576 05	.55790439 04	.55790439 04
44.	LH2 BELO VALVE	10.00	71.00	0.0	0.0	.12082576 05	.55790439 04	.55790439 04
45.	COLD HE QUAD 1	110.82	494.30	86.3	-75.6	.00000000 00	.10187921 06	.10187921 06
46.	COLD HE QUAD 2	110.82	494.30	113.8	20.0	.00000000 00	.10187921 06	.10187921 06
47.	APS PROP FD 1	61.88	248.00	0.0	-140.0	.00000000 00	.89110081 04	.89110081 04
48.	APS PROP FD 3	61.26	248.00	0.0	140.0	.00000000 00	.88220164 04	.88220164 04
49.	APS HELIUM	3.00	248.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
50.	HYDRAULIC OIL	14.50	110.00	-4.2	6.9	.83520000 04	.32625000 04	.32625000 04
51.	N2 HYD RESERV	1.80	135.80	-37.2	10.7	.00030000 00	.00000000 00	.00000000 00
52.	AIR HYD PUMP	0.50	130.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
53.	HE ENG PNEU	2.55	88.40	-22.0	14.6	.00000000 00	.00000000 00	.00000000 00
54.	HE VEH PNEU	1.00	164.40	61.0	17.5	.00000000 00	.00000000 00	.00000000 00
55.	GH2-START TANK	1.00	88.40	-22.4	14.6	.00000000 00	.00000000 00	.00000000 00
56.	ENV CONT FLUID	43.00	662.70	0.0	0.0	.66116800 06	.33049923 06	.33049923 06
	TOTAL REMAINING	133737.83	584.99	5.8	-2.4	.49341319 09	.25847864 11	.25852668 11
						SLF .10649834 06	SLF .55790047 07	SLF .55794100 07

SUMMARY PRINTOUT — TIME 500.000 — ITEMS REMAINING

SEQ	DESCRIPTION	MASS (POUNDS)	STATION (INCHES) R. ARM	L.ARM	V.ARM	MOI (POUND INCHES SQUARE) ROLL	PITCH	YAW
21.	SLA RING	91.00	1047.70	0.0	-1.8	.54150273 06	.24615865 06	.24615865 06
22.	COMMAND MODULE	12061.00	1251.00	0.1	5.2	.26326240 08	.27278087 08	.25592554 08
23.	SERVICE MODULE	9845.00	1124.30	0.8	-1.3	.29586512 08	.47581183 08	.44478875 08
24.	S/M PROPELLANT	22483.00	1124.40	27.2	-11.4	.35114633 08	.62252378 08	.66584272 08
31.	ADAPTER	3725.00	856.00	1.1	-2.9	.43367976 08	.59608379 08	.59044265 08
32.	INSTRUMNT UNIT	4492.10	698.00	-1.1	-10.7	.68055189 08	.36849222 08	.32015233 08
33.	S4B2D2 DRY STG	23055.00	328.07	5.7	-2.0	.26766999 09	.10166287 10	.10139224 10
34.	LOX ULLAGE GAS	302.54	256.57	0.0	0.0	.03000000 00	.00000000 00	.00000000 00
35.	LOX IN TANK	35526.74	188.72	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
36.	LOX IN PORTS	13.00	155.00	-25.0	13.0	.18722000 04	.29250000 04	.32500000 04
37.	LOX IN LINES	246.00	136.80	6.4	-9.9	.22718616 05	.22718616 05	.22718616 05
38.	LOX IN ENGINE	108.00	71.00	0.0	0.0	.13049182 06	.69253674 05	.69253674 05
39.	LOX BELO VALVE	39.00	71.00	0.0	0.0	.36247727 05	.16737132 05	.16737132 05
40.	LH2 ULLAGE GAS	373.40	501.34	0.0	0.0	.30000000 00	.00000000 00	.00000000 00
41.	LH2 IN TANK	8717.18	320.98	0.0	0.0	.00000000 00	.46806472 08	.46806472 08
42.	LH2 IN LINES	38.00	187.91	-58.9	-64.8	.44993827 05	.48051516 05	.48051516 05
43.	LH2 IN ENGINE	10.00	71.00	0.0	0.0	.12082576 05	.55790439 04	.55790439 04
44.	LH2 BELO VALVE	10.00	71.00	0.0	0.0	.12082576 05	.55790439 04	.55790439 04
45.	COLD HE QUAD 1	110.82	494.30	86.3	-75.6	.00000000 00	.10187921 06	.10187921 06
46.	COLD HE QUAD 2	110.82	494.30	113.8	20.0	.00000000 00	.10187921 06	.10187921 06
47.	APS PROP FD 1	61.88	248.00	0.0	-140.0	.00000000 00	.89110081 04	.89110081 04
48.	APS PROP FD 3	61.26	248.00	0.0	140.0	.00000000 00	.88220164 04	.88220164 04
49.	APS HELIUM	3.00	248.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
50.	HYDRAULIC OIL	14.50	110.00	-4.2	6.9	.83520000 04	.32625000 04	.32625000 04
51.	N2 HYD RESERV	1.80	135.80	-37.2	10.7	.00030000 00	.00000000 00	.00000000 00
52.	AIR HYD PUMP	0.50	130.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
53.	HE ENG PNEU	2.55	88.40	-22.0	14.6	.00000000 00	.00000000 00	.00000000 00
54.	HE VEH PNEU	1.00	164.40	61.0	17.5	.00000000 00	.00000000 00	.00000000 00
55.	GH2-START TANK	1.00	88.40	-22.4	14.6	.00000000 00	.00000000 00	.00000000 00
56.	ENV CONT FLUID	43.00	662.70	0.0	0.0	.66116800 06	.33049923 06	.33049923 06
	TOTAL REMAINING	121034.09	621.77	6.4	-2.7	.49276036 09	.24371502 11	.24373872 11
						SLF .12635743 06	SLF .51955946 07	SLF .51961741 07

TABLE AP 1-2 (Sheet 7 of 10)
MASS BREAKDOWN SUMMARY

S-IVB ENGINE CUTOFF COMMAND — TIME 588.464 — ITEMS REMAINING

SEQ	DESCRIPTION	MASS (POUNDS)	STATION (INCHES) H. ARM	L. ARM	V. ARM	MOI (POUND INCHES SQUARE) ROLL	PITCH	YAW
21.	SLA RING	91.00	1047.70	0.0	-1.8	.54150273 06	.24615865 06	.24615865 06
22.	COMMAND MODULE	12061.00	1251.00	0.1	5.2	.26326249 08	.22728087 08	.22582256 08
23.	SERVICE MODULE	9845.00	1124.30	0.0	-1.3	.29586512 08	.47581183 08	.46478875 08
24.	S/M PROPELLANT	22483.00	1124.40	27.2	-11.4	.35114633 08	.62252378 08	.60584222 08
31.	ADAPTER	3725.00	856.00	1.1	-2.9	.43367976 08	.59608379 08	.59044245 08
32.	INSTRUMNT UNIT	4402.10	698.00	-1.1	-10.7	.68055189 08	.36840222 08	.32915233 08
33.	S4B202 DRY STG	23055.00	328.07	5.7	-2.3	.26756999 09	.10166287 10	.10138224 10
34.	LOX ULLAGE GAS	367.29	245.93	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
35.	LOX IN TANK	3447.88	166.64	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
36.	LOX IN PORTS	11.00	155.00	-25.0	10.0	.18720000 04	.29250000 04	.32500000 04
37.	LOX IN LINES	246.00	136.80	6.4	-9.9	.22718616 05	.22718616 05	.22718616 05
38.	LOX IN ENGINE	108.00	71.00	0.0	0.0	.13049182 06	.60253674 05	.60253674 05
39.	LOX BELO VALVE	30.00	71.00	0.0	0.0	.34247727 05	.16737132 05	.16737132 05
40.	LH2 ULLAGE GAS	669.58	475.94	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
41.	LH2 IN TANK	1551.82	280.84	0.0	0.0	.00000000 00	.11902517 08	.11902517 08
42.	LH2 IN LINES	38.00	187.91	-50.9	-64.8	.44993827 05	.48951516 05	.48951516 05
43.	LH2 IN ENGINE	10.00	71.00	0.0	0.0	.12282574 05	.55790439 04	.55790439 04
44.	LH2 BELO VALVE	10.00	71.00	0.0	0.0	.12282574 05	.55790439 04	.55790439 04
45.	COLD HE QUAD 1	95.55	494.30	86.3	-75.6	.00000000 00	.87839635 05	.87839635 05
46.	COLD HE QUAD 2	95.55	494.30	113.8	20.0	.00000000 00	.87839635 05	.87839635 05
47.	APS PROP EP 1	61.70	248.00	0.0	-140.0	.00000000 00	.88847662 04	.88847662 04
48.	APS PROP EP 3	60.90	248.00	0.0	140.0	.00000000 00	.87695325 04	.87695325 04
49.	APS HELIUM	3.00	248.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
50.	HYDRAULIC OIL	14.50	110.00	-4.2	6.0	.83520000 04	.32625000 04	.32625000 04
51.	N2 HYD RESERV	1.90	135.80	-37.2	10.7	.00000000 00	.00000000 00	.00000000 00
52.	AIR HYD PUMP	0.50	130.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
53.	HE ENG PNEU	2.55	88.40	-22.0	14.6	.00000000 00	.00000000 00	.00000000 00
54.	HE VEH PNEU	1.00	164.60	61.0	17.5	.00000000 00	.00000000 00	.00000000 00
55.	GH2-START TANK	1.00	88.40	-22.4	14.6	.00000000 00	.00000000 00	.00000000 00
56.	ENV CONT FLUID	43.00	662.70	0.0	0.0	.66116800 06	.33049923 06	.33049923 06
	TOTAL REMAINING	82624.62	810.79	0.3	-3.9	.48971882 09	.14630938 11	.14631260 11
						SLF .10570094 06	SLF .31579426 07	SLF .31580121 07

S-IVB END OF THRUST DECAY — TIME 589.764 — ITEMS REMAINING

SEQ	DESCRIPTION	MASS (POUNDS)	STATION (INCHES) H. ARM	L. ARM	V. ARM	MOI (POUND INCHES SQUARE) ROLL	PITCH	YAW
21.	SLA RING	91.00	1047.70	0.0	-1.8	.54150273 06	.24615865 06	.24615865 06
22.	COMMAND MODULE	12061.00	1251.00	0.1	5.2	.26326249 08	.22728087 08	.22582256 08
23.	SERVICE MODULE	9845.00	1124.30	0.0	-1.3	.29586512 08	.47581183 08	.46478875 08
24.	S/M PROPELLANT	22483.00	1124.40	27.2	-11.4	.35114633 08	.62252378 08	.60584222 08
31.	ADAPTER	3725.00	856.00	1.1	-2.9	.43367976 08	.59608379 08	.59044245 08
32.	INSTRUMNT UNIT	4402.10	698.00	-1.1	-10.7	.68055189 08	.36840222 08	.32915233 08
33.	S4B202 DRY STG	23055.00	328.07	5.7	-2.3	.26756999 09	.10166287 10	.10138224 10
34.	LOX ULLAGE GAS	367.29	245.93	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
35.	LOX IN TANK	3531.88	166.47	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
36.	LOX IN PORTS	11.00	155.00	-25.0	10.0	.18720000 04	.29250000 04	.32500000 04
37.	LOX IN LINES	246.00	136.80	6.4	-9.9	.22718616 05	.22718616 05	.22718616 05
38.	LOX IN ENGINE	108.00	71.00	0.0	0.0	.13049182 06	.60253674 05	.60253674 05
39.	LOX BELO VALVE	-0.00	71.00	0.0	0.0	-.83549605-01	-.38574284-01	-.38574284-01
40.	LH2 ULLAGE GAS	471.00	475.84	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
41.	LH2 IN TANK	1526.82	279.80	0.0	0.0	.00000000 00	.11708030 08	.11708030 08
42.	LH2 IN LINES	38.00	187.91	-50.9	-64.8	.44993827 05	.48951516 05	.48951516 05
43.	LH2 IN ENGINE	10.00	71.00	0.0	0.0	.12282574 05	.55790439 04	.55790439 04
44.	LH2 BELO VALVE	-0.00	71.00	0.0	0.0	-.27278679-01	-.12503389-01	-.12503389-01
45.	COLD HE QUAD 1	95.55	494.30	86.3	-75.6	.00000000 00	.87839635 05	.87839635 05
46.	COLD HE QUAD 2	95.55	494.30	113.8	20.0	.00000000 00	.87839635 05	.87839635 05
47.	APS PROP EP 1	61.49	248.00	0.0	-140.0	.00000000 00	.88543997 04	.88543997 04
48.	APS PROP EP 3	60.74	248.00	0.0	140.0	.00000000 00	.87461484 04	.87461484 04
49.	APS HELIUM	3.00	248.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
50.	HYDRAULIC OIL	14.50	110.00	-4.2	6.0	.83520000 04	.32625000 04	.32625000 04
51.	N2 HYD RESERV	1.90	135.80	-37.2	10.7	.00000000 00	.00000000 00	.00000000 00
52.	AIR HYD PUMP	0.50	130.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
53.	HE ENG PNEU	2.55	88.40	-22.0	14.6	.00000000 00	.00000000 00	.00000000 00
54.	HE VEH PNEU	1.00	164.60	61.0	17.5	.00000000 00	.00000000 00	.00000000 00
55.	GH2-START TANK	1.00	88.40	-22.4	14.6	.00000000 00	.00000000 00	.00000000 00
56.	ENV CONT FLUID	43.00	662.70	0.0	0.0	.66116800 06	.33049923 06	.33049923 06
	TOTAL REMAINING	82444.46	812.20	9.3	-3.9	.48964487 09	.14554828 11	.14555145 11
						SLF .10548499 06	SLF .31415152 07	SLF .31415934 07

24 October 1966

TABLE AP 1-2 (Sheet 8 of 10)
MASS BREAKDOWN SUMMARY

COMMAND SERVICE MODULE SEPARATION — TIME 597.000 — ITEMS JETTISONED

SEQ	DESCRIPTION	MASS (POUNDS)	STATION (INCHES) H. ARM	L.ARM	V.ARM	MOI (POUND INCHES SQUARE) ROLL	PITCH	YAW
21.	SLA RING	91.00	1067.70	0.0	-1.9	.54159273 04	.24615865 04	.24615865 04
22.	COMMAND MODULE	12541.00	1251.00	0.1	5.2	.24324240 08	.22728087 08	.22592254 08
23.	SERVICE MODULE	9865.00	1124.30	0.8	-1.3	.29596512 08	.47581183 08	.44479875 08
24.	S/M PROPELLANT	22683.00	1124.40	27.2	-11.4	.35114633 08	.62252378 08	.64584222 08
	TOTAL JETTISONED	44680.00	1158.55	14.0	-4.6	.10185556 09	.27709710 09	.29385588 09
						SLF .21994531 05	SLF .59806499 05	SLF .61267476 05

COMMAND SERVICE MODULE SEPARATION — TIME 597.000 — ITEMS REMAINING

SEQ	DESCRIPTION	MASS (POUNDS)	STATION (INCHES) H. ARM	L.ARM	V.ARM	MOI (POUND INCHES SQUARE) ROLL	PITCH	YAW
31.	ADAPTER	3725.00	845.70	1.1	-2.9	.13611894 09	.87540813 08	.87540813 08
32.	INSTRUMNT UNIT	4492.10	498.00	-1.1	-10.7	.68035180 08	.36840222 08	.32915233 08
33.	S4B202 DRY STG	23055.00	328.07	5.7	-2.0	.26756999 09	.10164287 10	.10138226 10
34.	LOX ULLAGE GAS	343.32	245.88	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
35.	LOX IN TANK	3517.41	144.45	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
36.	LOX IN PORTS	13.00	155.00	-25.0	10.0	.18720000 04	.29250000 04	.32500000 04
37.	LOX IN LINES	244.00	134.80	6.4	-9.9	.22718614 05	.22718614 05	.22718614 05
38.	LOX IN ENGINE	108.00	71.00	0.0	0.0	.13049182 06	.60253674 05	.60253674 05
39.	LOX BELO VALVE	-0.00	71.00	0.0	0.0	-.83540605-01	-.38574284-01	-.38574284-01
40.	LH2 ULLAGE GAS	475.71	475.82	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
41.	LH2 IN TANK	1822.10	279.75	0.0	0.0	.00000000 00	.11671344 08	.11671344 08
42.	LH2 IN LINES	38.00	187.91	-59.0	-64.8	.44993827 05	.48051516 05	.48051516 05
43.	LH2 IN ENGINE	10.00	71.00	0.0	0.0	.12082574 05	.55790439 04	.55790439 04
44.	LH2 BELO VALVE	-0.00	71.00	0.0	0.0	-.27678679-01	-.12803388-01	-.12803388-01
45.	COLD HE QUAD 1	95.55	494.30	84.3	-75.6	.00000000 00	.87839635 05	.87839635 05
46.	COLD HE QUAD 2	95.55	494.30	113.8	20.0	.00000000 00	.87839635 05	.87839635 05
47.	APS PROP FD 1	60.31	248.00	0.0	-140.0	.00000000 00	.86850585 04	.86850585 04
48.	APS PROP FD 3	59.83	248.00	0.0	140.0	.00000000 00	.86155137 04	.86155137 04
49.	APS HELIUM	3.00	248.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
50.	HYDRAULIC OIL	14.50	110.00	-4.2	6.0	.83520000 04	.32625000 04	.32625000 04
51.	N2 HYD RESERV	1.80	135.80	-37.2	10.7	.00000000 00	.00000000 00	.00000000 00
52.	AIR HYD PUMP	0.50	130.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
53.	HE ENG PNEU	2.55	88.40	-22.0	14.6	.00000000 00	.00000000 00	.00000000 00
54.	HE VEH PNEU	1.00	164.60	61.0	17.5	.00000000 00	.00000000 00	.00000000 00
55.	GH2-START TANK	1.00	88.40	-22.4	14.6	.00000000 00	.00000000 00	.00000000 00
56.	ENV CONT FLUID	43.00	662.70	0.0	0.0	.66116800 06	.33049023 06	.33049023 06
	TOTAL REMAINING	37924.23	405.61	3.9	-3.9	.47858027 09	.26824948 10	.26746350 10
						SLF .10329680 06	SLF .57899886 06	SLF .57729341 06

SERVICE PROPULSION SYSTEM IGNITION — TIME 610.200 — ITEMS REMAINING

SEQ	DESCRIPTION	MASS (POUNDS)	STATION (INCHES) H. ARM	L.ARM	V.ARM	MOI (POUND INCHES SQUARE) ROLL	PITCH	YAW
31.	ADAPTER	2579.34	827.20	-55.3	-64.4	.36850393 08	.25683740 08	.25716147 08
32.	INSTRUMNT UNIT	4492.10	498.00	-1.1	-10.7	.68035180 08	.36840222 08	.32915233 08
33.	S4B202 DRY STG	23055.00	328.07	5.7	-2.0	.26744999 09	.10164287 10	.10138226 10
34.	LOX ULLAGE GAS	343.32	245.88	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
35.	LOX IN TANK	3504.21	144.43	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
36.	LOX IN PORTS	13.00	155.00	-25.0	10.0	.18720000 04	.29250000 04	.32500000 04
37.	LOX IN LINES	244.00	134.80	6.4	-9.9	.22718614 05	.22718614 05	.22718614 05
38.	LOX IN ENGINE	108.00	71.00	0.0	0.0	.13049182 06	.60253674 05	.60253674 05
39.	LOX BELO VALVE	-0.00	71.00	0.0	0.0	-.83540605-01	-.38574284-01	-.38574284-01
40.	LH2 ULLAGE GAS	484.32	475.70	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
41.	LH2 IN TANK	1813.40	279.66	0.0	0.0	.00000000 00	.11604430 08	.11604430 08
42.	LH2 IN LINES	38.00	187.91	-59.0	-64.8	.44993827 05	.48051516 05	.48051516 05
43.	LH2 IN ENGINE	10.00	71.00	0.0	0.0	.12082574 05	.55790439 04	.55790439 04
44.	LH2 BELO VALVE	-0.00	71.00	0.0	0.0	-.27678679-01	-.12803388-01	-.12803388-01
45.	COLD HE QUAD 1	95.55	494.30	84.3	-75.6	.00000000 00	.87839635 05	.87839635 05
46.	COLD HE QUAD 2	95.55	494.30	113.8	20.0	.00000000 00	.87839635 05	.87839635 05
47.	APS PROP FD 1	58.08	248.00	0.0	-140.0	.00000000 00	.83630333 04	.83630333 04
48.	APS PROP FD 3	57.95	248.00	0.0	140.0	.00000000 00	.83450758 04	.83450758 04
49.	APS HELIUM	3.00	248.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
50.	HYDRAULIC OIL	14.50	110.00	-4.2	6.0	.83520000 04	.32625000 04	.32625000 04
51.	N2 HYD RESERV	1.80	135.80	-37.2	10.7	.00000000 00	.00000000 00	.00000000 00
52.	AIR HYD PUMP	0.50	130.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
53.	HE ENG PNEU	2.55	88.40	-22.0	14.6	.00000000 00	.00000000 00	.00000000 00
54.	HE VEH PNEU	1.00	164.60	61.0	17.5	.00000000 00	.00000000 00	.00000000 00
55.	GH2-START TANK	1.00	88.40	-22.4	14.6	.00000000 00	.00000000 00	.00000000 00
56.	ENV CONT FLUID	43.00	662.70	0.0	0.0	.66116800 06	.33049023 06	.33049023 06
	TOTAL REMAINING	36761.27	390.74	0.0	-7.4	.39653449 09	.23575191 10	.23541999 10
						SLF .85588031 05	SLF .50884515 06	SLF .50813267 06

TABLE AP 1-2 (Sheet 9 of 10)
MASS BREAKDOWN SUMMARY

SUMMARY PRINTOUT — TIME 700.000 — ITEMS REMAINING

SEQ	DESCRIPTION	MASS (POUNDS)	STATION (INCHES) H. ARM	L.ARM	V.ARM	MOI (POUND INCHES SQUARE) ROLL	PITCH	YAW
31.	ADAPTER	2579.60	827.20	-55.3	-64.4	.36863393 08	.25683740 08	.30716168 08
32.	INSTRUMNT UNIT	4492.10	698.00	-1.1	-10.7	.68025180 08	.36840222 08	.32915233 08
33.	S4B2G2 DRY STG	23055.00	328.07	5.7	-2.0	.26766999 09	.10166287 10	.10138226 10
34.	LOX ULLAGE GAS	223.32	245.81	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
35.	LOX IN TANK	3314.41	166.12	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
36.	LOX IN PORTS	13.00	155.00	-25.0	10.0	.18720000 04	.29250000 04	.32500000 04
37.	LOX IN LINES	246.00	136.80	6.4	-9.9	.22718616 05	.22718616 05	.22718616 05
38.	LOX IN ENGINE	108.00	71.00	0.0	0.0	.13049182 04	.60253674 05	.60253674 05
39.	LOX BELO VALVE	-0.00	71.00	0.0	0.0	-.83543605-01	-.38574284-01	-.38574284-01
40.	LH2 ULLAGE GAS	608.07	475.28	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
41.	LH2 IN TANK	1389.79	278.30	0.0	0.0	.00000000 00	.13643949 08	.13643949 08
42.	LH2 IN LINES	38.00	197.91	-59.9	-64.8	.44993827 05	.48051516 05	.48051516 05
43.	LH2 IN ENGINE	10.00	71.00	0.0	0.0	.12582576 05	.55790439 04	.55790439 04
44.	LH2 BELO VALVE	-0.00	71.00	0.0	0.0	-.27078679-01	-.12503388-01	-.12503388-01
45.	COLD HE QUAD 1	95.55	494.30	86.3	-75.6	.00000000 00	.87839635 05	.87839635 05
46.	COLD HE QUAD 2	95.55	494.30	113.8	20.0	.00000000 00	.87839635 05	.87839635 05
47.	APS PROP FD 1	45.36	248.00	0.0	-140.0	.00000000 00	.69018380 04	.69018380 04
48.	APS PROP FD 2	38.00	248.00	0.0	140.0	.00000000 00	.54720027 04	.54720027 04
49.	APS HELIUM	3.00	244.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
50.	HYDRAULIC OIL	14.50	110.00	-4.2	6.0	.83520000 04	.32625000 04	.32625000 04
51.	N2 HYD RESERV	1.80	135.80	-37.2	10.7	.00000000 00	.00000000 00	.00000000 00
52.	AIR HYD PUMP	0.50	130.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
53.	HE ENG PNEU	2.55	89.40	-22.0	14.6	.00000000 00	.00000000 00	.00000000 00
54.	HE VEH PNEU	1.00	164.60	61.9	17.5	.00000000 00	.00000000 00	.00000000 00
55.	GH2-START TANK	1.00	89.40	-22.4	14.6	.00000000 00	.00000000 00	.00000000 00
56.	ENV CONT FLUID	43.00	662.70	0.0	0.0	.66116800 06	.33049923 06	.33049923 06
	TOTAL REMAINING	36621.41	391.76	0.0	-7.4	.39591820 09	.23509931 10	.23483094 10
						SLF .85455019 05	SLF .50743851 06	SLF .50685737 06

SUMMARY PRINTOUT — TIME 800.000 — ITEMS REMAINING

SEQ	DESCRIPTION	MASS (POUNDS)	STATION (INCHES) H. ARM	L.ARM	V.ARM	MOI (POUND INCHES SQUARE) ROLL	PITCH	YAW
31.	ADAPTER	2579.60	827.20	-55.3	-64.4	.36863393 08	.25683740 08	.30716168 08
32.	INSTRUMNT UNIT	4492.10	698.00	-1.1	-10.7	.68025180 08	.36840222 08	.32915233 08
33.	S4B2G2 DRY STG	23055.00	328.07	5.7	-2.0	.26766999 09	.10166287 10	.10138226 10
34.	LOX ULLAGE GAS	223.32	245.81	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
35.	LOX IN TANK	3314.41	166.12	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
36.	LOX IN PORTS	13.00	155.00	-25.0	10.0	.18720000 04	.29250000 04	.32500000 04
37.	LOX IN LINES	246.00	136.80	6.4	-9.9	.22718616 05	.22718616 05	.22718616 05
38.	LOX IN ENGINE	108.00	71.00	0.0	0.0	.13049182 04	.60253674 05	.60253674 05
39.	LOX BELO VALVE	-0.00	71.00	0.0	0.0	-.83543605-01	-.38574284-01	-.38574284-01
40.	LH2 ULLAGE GAS	608.07	475.28	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
41.	LH2 IN TANK	1389.79	278.30	0.0	0.0	.00000000 00	.13643949 08	.13643949 08
42.	LH2 IN LINES	38.00	197.91	-59.9	-64.8	.44993827 05	.48051516 05	.48051516 05
43.	LH2 IN ENGINE	10.00	71.00	0.0	0.0	.12582576 05	.55790439 04	.55790439 04
44.	LH2 BELO VALVE	-0.00	71.00	0.0	0.0	-.27078679-01	-.12503388-01	-.12503388-01
45.	COLD HE QUAD 1	95.55	494.30	86.3	-75.6	.00000000 00	.87839635 05	.87839635 05
46.	COLD HE QUAD 2	95.55	494.30	113.8	20.0	.00000000 00	.87839635 05	.87839635 05
47.	APS PROP FD 1	45.36	248.00	0.0	-140.0	.00000000 00	.65317977 04	.65317977 04
48.	APS PROP FD 2	34.44	248.00	0.0	140.0	.00000000 00	.52468080 04	.52468080 04
49.	APS HELIUM	3.00	248.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
50.	HYDRAULIC OIL	14.50	110.00	-4.2	6.0	.83520000 04	.32625000 04	.32625000 04
51.	N2 HYD RESERV	1.80	135.80	-37.2	10.7	.00000000 00	.00000000 00	.00000000 00
52.	AIR HYD PUMP	0.50	130.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
53.	HE ENG PNEU	2.55	89.40	-22.0	14.6	.00000000 00	.00000000 00	.00000000 00
54.	HE VEH PNEU	1.00	164.60	61.9	17.5	.00000000 00	.00000000 00	.00000000 00
55.	GH2-START TANK	1.00	89.40	-22.4	14.6	.00000000 00	.00000000 00	.00000000 00
56.	ENV CONT FLUID	43.00	662.70	0.0	0.0	.66116800 06	.33049923 06	.33049923 06
	TOTAL REMAINING	36417.48	393.11	0.0	-7.5	.39582798 09	.23430987 10	.23404844 10
						SLF .85435540 05	SLF .50573458 06	SLF .50517291 06

TABLE AP 1-2 (Sheet 10 of 10)
MASS BREAKDOWN SUMMARY

LOSS OF SIGNAL TIME 941.000 ITEMS REMAINING

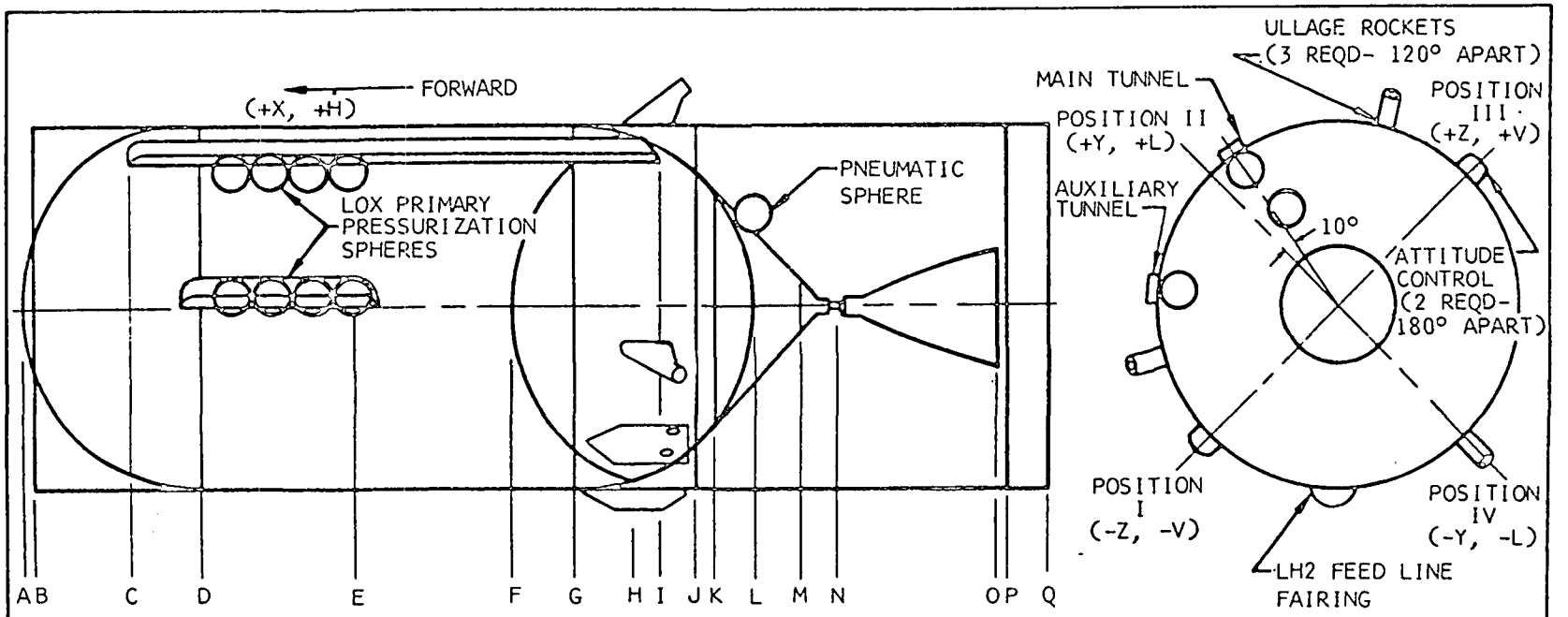
SEQ DESCRIPTION	MASS (POUNDS)	STATION(INCHES) H. ARM	L.ARM	V.ARM	MOI (POUND INCHES SQUARE) ROLL	PITCH	YAW
31. ADAPTER	2579.60	827.20	-55.3	-64.4	.36860393 08	.25683740 08	.30716168 08
32. INSTRUMNT UNIT	4492.10	698.90	-1.1	-10.7	.68005189 08	.36840222 08	.32915233 08
33. S4B202 DRY STG	23055.00	328.07	5.7	-2.0	.26766999 09	.10166287 10	.10138226 10
34. LOX ULLAGE GAS	82.32	245.76	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
35. LOX IN TANK	3173.41	165.87	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
36. LOX IN PORTS	13.00	155.00	-25.0	10.0	.18720000 04	.29250000 04	.32500000 03
37. LOX IN LINES	246.00	136.80	6.4	-9.9	.22718616 05	.22718616 05	.22718616 05
38. LOX IN ENGINE	108.00	71.00	0.0	0.0	.13049182 06	.60253674 05	.60253674 05
39. LOX BELO VALVE	-0.00	71.00	0.0	0.0	-.83540605-01	-.38574284-01	-.38574284-01
40. LH2 ULLAGE GAS	700.00	474.90	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
41. LH2 IN TANK	1297.82	277.43	0.0	0.0	.00000000 00	.99323236 07	.99323236 07
42. LH2 IN LINES	38.00	187.91	-59.9	-64.8	.44993827 05	.48051516 05	.48051516 05
43. LH2 IN ENGINE	10.00	71.00	0.0	0.0	.12082576 05	.55790439 04	.55790439 04
44. LH2 BELO VALVE	-0.00	71.00	0.0	0.0	-.27078679-01	-.12503388-01	-.12503388-01
45. COLD HE QUAD 1	95.55	494.30	86.3	-75.6	.00000000 00	.87839635 05	.87839635 05
46. COLD HE QUAD 2	95.55	494.30	113.8	20.0	.00000000 00	.87839635 05	.87839635 05
47. APS PROP FP 1	44.40	248.00	0.0	-140.0	.00000000 00	.63936086 04	.63936086 04
48. APS PROP FP 3	34.00	248.00	0.0	140.0	.00000000 00	.48960157 04	.48960157 04
49. APS HELIUM	3.00	248.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
50. HYDRAULIC OIL	14.50	110.00	-4.2	6.0	.83520000 04	.32625000 04	.32625000 04
51. N2 HYD RESERV	1.80	135.80	-37.2	10.7	.00000000 00	.00000000 00	.00000000 00
52. AIR HYD PUMP	0.50	130.00	0.0	0.0	.00000000 00	.00000000 00	.00000000 00
53. HE ENG PNEU	2.55	88.40	-22.0	14.6	.00000000 00	.00000000 00	.00000000 00
54. HE VEH PNEU	1.00	164.60	61.0	17.5	.00000000 00	.00000000 00	.00000000 00
55. GH2-START TANK	1.00	88.40	-22.4	14.6	.00000000 00	.00000000 00	.00000000 00
56. ENV CONT FLUID	43.00	662.70	0.0	0.0	.66116800 06	.33049923 06	.33049923 06
TOTAL REMAINING	36132.09	395.02	0.0	-7.5	.39574234 09	.23317786 10	.23292620 10
					SLF .85417054 05	SLF .50329125 06	SLF .50274807 06

TABLE AP 1-3 (Sheet 1 of 2)
MASS CHARACTERISTICS SUMMARY (WS11)

TIME (SECONDS)	MASS (POUNDS)	M.ARM (INCHES)	L.ARM (INCHES)	V.ARM (INCHES)	ROLL MOI (SLUG FT.SQ.) / ROLL POI (POUND IN.SQ)	PITCH MOI (SLUG FT.SQ.) / PITCH POI (POUND IN.SQ)	YAW MOI (SLUG FT.SQ.) / YAW POI (POUND IN.SQ)
0.930	316147.04	448.48	2.5	-1.0	109961.65 1488122.50	9361389.13 -151160410.00	9362599.50 329392268.00
100.000	316097.04	448.48	2.5	-1.0	109778.90 1488250.69	9361224.13 -151158958.00	9362434.63 329388784.00
144.180	316097.04	448.48	2.5	-1.0	109778.90 1488250.69	9361224.13 -151158958.00	9362434.63 329388784.00
144.270	316092.87	448.49	2.5	-1.0	109760.77 1488261.38	9361170.38 -151157998.00	9362380.88 329386480.00
144.270	316063.97	448.51	2.5	-1.0	109655.73 1488335.50	9360713.38 -151150598.00	9361923.75 329368708.00
145.624	316000.94	448.55	2.5	-1.0	109381.79 1488497.19	9359900.63 -151136096.00	9361112.25 329333884.00
147.980	315631.88	448.67	2.5	-1.0	108908.88 1492332.94	9358396.13 -151078976.00	9359607.75 329210824.00
149.126	315242.20	448.77	2.5	-1.0	108909.29 1494741.06	9357561.00 -151038930.00	9358772.50 329121524.00
149.260	315185.64	448.78	2.5	-1.0	108909.19 1494594.56	9357418.13 -151038956.00	9358629.75 329117704.00
151.620	314129.02	449.09	2.5	-1.0	108904.96 1498913.75	9354218.50 -150937768.00	9355428.13 328872568.00
156.222	311804.25	449.82	2.5	-1.0	108896.14 1508092.00	9346877.13 -150697202.00	9348082.63 328292608.00
156.222	311581.95	449.98	2.5	-1.0	108016.27 1508255.44	9343940.75 -150679580.00	9345146.00 328185328.00
168.930	304879.59	452.29	2.6	-1.1	107991.16 1534850.75	9320504.38 -149922748.00	9321697.88 326361384.00
168.930	296268.60	421.46	2.6	-1.1	107421.75 1519006.06	7147489.19 -160200134.00	7148671.75 350394940.00
200.000	279811.51	426.57	2.8	-1.2	107356.47 1590340.75	7117098.69 -158516838.00	7118249.13 346317908.00
200.001	279810.99	426.57	2.8	-1.2	107356.47 1590344.19	7117097.25 -158516716.00	7118247.69 346317772.00
250.000	253309.17	437.95	3.1	-1.3	107250.38 1718504.31	7014410.88 -154784616.00	7015497.13 337310244.00
300.000	226806.28	454.03	3.4	-1.4	107131.32 1868058.38	6866682.44 -149543518.00	6867695.50 324690556.00
350.000	200337.20	476.31	3.9	-1.6	106994.30 2047280.81	6658409.19 -142305916.00	6659336.50 307296800.00
400.000	173842.35	507.77	4.5	-1.9	106830.86 2270129.38	6355033.38 -132125089.00	6355856.25 282868996.00
450.000	147333.30	553.28	5.3	-2.2	106626.77 2560106.63	5901802.69 -117433723.00	5902492.63 247666730.00
475.720	133737.83	584.89	5.8	-2.4	106498.43 2747832.44	5579009.50 -107251043.00	5579614.88 223289042.00
500.000	121034.09	621.77	6.4	-2.7	106357.52 2957677.25	5195599.13 -95380063.00	5196110.63 194884806.00
550.000	98894.00	711.10	7.8	-3.3	106033.74 3445539.69	4249039.50 -66678873.00	4249334.31 126276234.00
588.464	82624.62	810.79	9.3	-3.9	105701.04 3959062.13	3157945.38 -34700513.00	3158014.81 49893034.00

TABLE AP 1-3 (Sheet 2 of 2)
MASS CHARACTERISTICS SUMMARY (WS11)

TIME (SECONDS)	MASS (POUNDS)	H.ARM (INCHES)	L.ARM (INCHES)	V.ARM (INCHES)	ROLL MOI (SLUG FT.SQ.) / ROLL POI (POUND IN.SQ)	PITCH MOI (SLUG FT.SQ.) / PITCH POI (POUND IN.SQ)	YAW MOI (SLUG FT.SQ.) / YAW POI (POUND IN.SQ)
588.465	82624.48	810.79	9.3	-3.9	105701.03 3959066.88	3157932.84 -34700181.00	3158002.31 49892202.00
589.764	82444.66	812.20	9.3	-3.9	105685.07 3965532.44	3141517.91 -34251101.00	3141596.16 48808882.00
596.990	82404.28	812.50	9.3	-3.9	105675.45 3966651.50	3138273.63 -34175677.00	3138349.94 48577714.00
597.000	82404.22	812.03	9.3	-3.9	125737.99 3966653.06	3143659.16 -34214003.00	3143857.25 48893370.00
597.000	37924.23	405.61	3.9	-3.0	103296.89 -4779491.06	578990.37 -21514395.50	577293.91 -86495821.00
610.000	37907.48	405.75	3.9	-3.0	103281.06 -4779557.13	578775.42 -21509481.00	577094.69 -86515973.00
610.001	37907.48	405.75	3.9	-3.0	103281.05 -4779557.13	578775.47 -21509481.00	577094.74 -86515973.00
610.190	37906.94	405.75	3.9	-3.0	103279.54 -4779485.75	578769.41 -21506496.50	577090.19 -86516450.00
610.200	36761.27	390.74	0.0	-7.4	85588.11 3981230.31	508845.59 -90816344.00	508131.11 -148407184.00
625.000	36719.09	390.99	0.0	-7.4	85466.94 3982080.31	508438.65 -90571263.00	507845.66 -148413522.00
625.001	36719.08	390.99	0.0	-7.4	85466.93 3982080.31	508438.63 -90571248.00	507845.64 -148413522.00
650.000	36693.26	391.22	0.0	-7.4	85463.06 3982090.69	508137.43 -90504791.00	507548.32 -148413932.00
680.000	36662.27	391.50	0.0	-7.4	85458.42 3982103.19	507774.21 -90424866.00	507189.74 -148414426.00
700.000	36621.61	391.76	0.0	-7.4	85455.08 3982118.69	507438.95 -90349847.00	506857.81 -148414894.00
710.000	36601.28	391.90	0.0	-7.4	85453.42 3982126.44	507270.79 -90312264.00	506691.32 -148415130.00
710.001	36601.28	391.90	0.0	-7.4	85453.42 3982126.44	507270.78 -90312261.00	506691.30 -148415130.00
750.000	36518.69	392.44	0.0	-7.4	85442.15 3982145.31	506584.30 -90198138.00	506016.09 -148416094.00
750.001	36518.68	392.44	0.0	-7.4	85442.15 3982145.31	506584.29 -90198135.00	506016.08 -148416094.00
800.000	36417.48	393.11	0.0	-7.5	85435.61 3982185.31	505735.02 -90005714.00	505173.34 -148417268.00
850.000	36316.28	393.78	0.0	-7.5	85429.07 3982225.56	504876.78 -89812034.00	504321.66 -148418460.00
900.000	36215.07	394.46	0.0	-7.5	85422.51 3982266.19	504009.56 -89617101.00	503461.00 -148419658.00
941.000	36132.09	395.02	0.0	-7.5	85417.13 3982299.56	503291.69 -89456310.00	502748.51 -148420648.00



	INSTALLATION	STATION
A.	FWD BULKHEAD (FWD END)	684.6
B.	FWD SKIRT (FWD END)	676.7
C.	MAIN TUNNEL (FWD END)	607.7
D.	FWD SKIRT (AFT END)	554.7
	FWD BULKHEAD (AFT END)	553.0
E.	COLD HELIUM SPHERES (8 REQD - 26.9" ℄ TO ℄)	454.0
F.	COMMON BULKHEAD (FWD END)	335.2
	AFT BULKHEAD (FWD END)	287.8
G.	AFT SKIRT (FWD END)	286.1
	LH2 FEED LINE FAIRING (FWD END)	286.1
	AUXILIARY PROPULSION MODULE (FWD END)	285.5
	ULLAGE ROCKET (FWD END)	245.3
H.	COMMON BULKHEAD (AFT END)	244.4
I.	MAIN TUNNEL (AFT END)	224.1

	INSTALLATION	STATION
	AUXILIARY PROPULSION MODULE (AFT END)	205.1
	ULLAGE ROCKET FAIRING (AFT END)	204.6
	LH2 FEED LINE FAIRING (AFT END)	202.7
J.	AFT SKIRT (AFT END)	200.6
	INTERSTAGE (FWD END)	200.6
K.	THRUST STRUCTURE/AFT BULKHEAD TANGENT POINT	186.9
	AMBIENT HELIUM SPHERES	158.6
L.	AFT BULKHEAD (AFT END)	156.3
M.	THRUST STRUCTURE SKIN (AFT END)	121.3
N.	GIMBAL STATION	100.0
O.	ENGINE NOZZLE (AFT END)	-16.0
P.	INTERSTAGE (AFT END)	-23.9
	AERODYNAMIC FAIRING (FWD END)	-23.5
Q.	AERODYNAMIC FAIRING (AFT END)	-50.9

Figure AP 1-1. Saturn S-IVB/IB Installation - Station List Saturn AS-202 Vehicle Liftoff

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1. ENGINE PERFORMANCE PROGRAM (AA89)

This appendix contains the digital printout of the AA89 computer program (table AP 2-1), one of the methods employed in the propulsion system performance reconstruction of the S-IVB-202 stage flight evaluation. The performance analysis and associated plots are presented in section 8.

Abbreviations appearing on the printout are defined as follows:

Printout Symbol	Definition
A SUB M	Stage axial acceleration (g)
C SUB FEV	Engine vacuum thrust coefficient
DEL	PU valve position (deg)
DELTA P SUB F	LH2 low pressure feed line differential pressure (psia)
DELTA P SUB O	LOX low pressure feed line differential pressure (psia)
EMR	Engine mixture ratio (LOX/LH2)
FPS	LH2 pump speed (rpm)
F SUB E	Stage thrust (lbf)
FUEL OVB	Total LH2 overboard (lbm)
GGMR	Gas generator mixture ratio (LOX/LH2)
H SUB F	Height of LH2 above pump inlet (in.); computed from height versus volume polynominal
H SUB O	Height of LOX above pump inlet (in.); computed from height versus volume polynominal
IMP SUB T	Stage total impulse (lb-sec)
ISP	Stage longitudinal specific impulse (sec); stage longitudinal thrust divided by stage mass flowrate
LPS	LOX pump speed (rpm)
OXID OVB	Total LOX overboard (lbm)
PCC	Thrust chamber pressure (inj) (psia)
PFPI	LH2 pump inlet pressure, total (psia)
POPI	LOX pump inlet pressure, total (psia)
TFPI	LH2 pump inlet temperature (deg R)
TOPI	LOX pump inlet temperature (deg R)

Printout Symbol	Definition
P SUB HF	LH2 head pressure at pump inlet (psia)
P SUB HO	LOX head pressure at pump inlet (psia)
RHO SUB F	LH2 bulk density (lbm/ft^3)
RHO SUB O	LOX bulk density (lbm/ft^3)
TIME	Time from S-IVB stage engine start (sec)
TTMF	Total LH2 ullage mass (lbm)
TTMO	Total LOX ullage mass (lbm)
TTP SUB F	Fuel tank top pressure (psia)
TTP SUB O	Oxidizer tank top pressure (psia)
V SUB F	LH2 volume in tank (ft^3)
WDOT FBO	LH2 boiloff rate (lbm/sec)
WDOT FGG	Gas generator LH2 flowrate (lbm/sec)
WDOT FPR	LH2 pressurant flowrate (lbm/sec)
WDOT HE	Helium pressurant flowrate (lbm/sec)
WDOT OBO	LOX boiloff rate (lbm/sec)
WDOT OGG	Gas generator LOX flowrate (lbm/sec)
WDOT SUB F	LH2 flowrate, pump inlet (lbm/sec)
WDOT SUB O	LOX flowrate, pump inlet (lbm/sec)
WDOT SUB T	Total propellant consumption, includes auxiliary flows (lb/sec)
W SUB FT	Total LH2 mass boiled off (lbm)
W SUB O ERROR	Equivalent LOX mass error, defined as LH2 onboard times reference mixture ratio of PU system subtracted from LOX mass onboard (lbm)
W SUB OT	Total LOX mass boiled off (lbm)
W SUB V	Vehicle mass (lbm)
WF IN TANK	Total LH2 in LH2 tank (lbm)
WF PU	PU indicated LH2 mass (lbm)
WF USABLE	Usable LH2 mass in tank (lbm)
WO IN TANK	Total LOX in LOX tank (lbm)
WO PU	PU indicated LOX mass (lbm)
WO USABLE	Usable LOX mass in tank (lbm)

TABLE AP 2-1 (Sheet 1 of 2)
ENGINE PERFORMANCE PROGRAM (AA89)

1	0.000	0.000	0.000	0.000	34.580	1	75.000	445.298	80.550	525.846	33.766
2	0.000	2.000	1.780	226.608	402.579	2	223492.219	38.795	30.702	195.757	440.631
3	0.030	2.000	1.780	7411.647	6830.504	3	5.528	40.948	30.115	2269.528	7154.623
4	0.000	-0.000	0.000	0.000	0.000	4	425.015	164.672	37.667	160316.266	33067.816
5	1.715	80.006	5.422	192344.000	35943.030	5	1.730	70.991	4.346	160316.266	33067.816
6	0.000	0.406	0.000	192464.000	36105.000	6	759.154	0.406	0.000	160439.266	33223.816
7	0.030	0.000	0.000	192945.000	37016.000	7	8897.120	0.000	0.365	160839.791	31099.529
8	0.000	3.111	45.000	193312.000	37084.000	8	27051.216	3.111	45.000	161256.791	31133.529
9	0.000	33.889	165.000	0.000	0.000	9	0.000	64.372	190.913	32024.725	5919.557
10	-84.973	0.000	0.000	0.000	0.000	10	9.556	30.484	0.000	0.000	0.000
11	330.000	37.000	210.000	0.000	0.000	11	330.000	67.483	235.913	0.000	0.000
12	0.000	0.000	0.000	0.000	314415.000	12	0.921	3.638	3.949	0.000	276414.320
13	0.000		0.000		0.000	13	0.809		25.914		16131889.875
1	1.000	0.000	26.018	26.018	36.341	1	100.000	444.556	80.268	524.824	33.843
2	0.000	-0.079	-0.644	200.999	428.135	2	223015.756	36.424	27.989	188.164	425.446
3	0.000	-0.079	-0.804	2369.174	6784.242	3	5.538	39.133	27.420	2112.406	6695.515
4	0.000	-6.448	-1.483	192343.592	35939.958	4	424.934	164.687	37.918	149181.223	28069.719
5	1.714	81.440	5.459	192343.592	35939.958	5	1.730	70.888	4.341	149181.223	28069.719
6	0.000	0.406	0.000	192463.592	36101.958	6	757.555	0.406	0.000	149301.221	28231.719
7	0.030	0.000	0.051	192944.592	37032.922	7	8890.702	0.000	0.367	149745.195	29068.528
8	6573.481	3.111	45.000	193311.592	37080.922	8	27025.294	3.111	45.000	150112.195	29116.528
9	0.000	34.295	165.026	0.000	3.052	9	0.000	74.534	200.064	43159.158	7932.437
10	11.783	0.406	0.000	0.000	0.000	10	8.679	40.645	0.000	0.000	0.000
11	330.000	37.406	210.026	0.000	0.000	11	330.000	77.645	245.064	0.000	0.000
12	0.000	0.000	1.178	0.000	314411.512	12	0.921	3.631	3.942	0.000	263247.723
13	0.000		0.026		0.000	13	0.847		35.065		21719202.530
1	2.000	145.285	53.024	198.309	-0.072	1	125.000	446.202	80.417	526.620	33.972
2	90489.926	42.049	40.570	226.403	485.401	2	223743.791	40.249	28.877	181.218	410.133
3	2.740	43.829	40.211	2723.491	8502.017	3	5.549	43.035	28.318	1955.422	6234.025
4	456.307	165.044	37.911	192286.635	35894.592	4	424.868	164.734	37.988	138045.809	26074.579
5	1.699	70.824	4.350	192286.635	35894.592	5	1.730	70.880	4.339	138045.809	26074.579
6	312.942	0.406	0.000	192406.635	36056.592	6	759.744	0.406	0.000	138165.807	26235.579
7	3094.526	0.000	0.103	192887.586	36987.013	7	8901.482	0.000	0.369	138600.229	27049.519
8	17545.829	3.111	45.000	193254.586	37035.013	8	27076.057	3.111	45.000	138967.229	27097.519
9	0.000	34.702	165.103	55.600	48.894	9	0.000	84.695	209.262	54291.965	9942.218
10	11.862	0.813	0.000	0.000	0.000	10	7.794	50.806	0.000	0.000	0.000
11	330.000	37.813	210.103	0.000	0.000	11	330.000	87.806	254.262	0.000	0.000
12	0.475	1.211	2.548	0.000	314308.598	12	0.923	3.644	3.949	0.000	250083.746
13	0.288		0.103		29167.793	13	0.895		44.263		27304540.750
1	3.000	347.974	77.028	425.002	0.024	1	150.000	445.404	79.975	525.378	33.972
2	189752.697	41.172	40.474	225.920	484.531	2	223129.965	38.254	27.631	175.124	394.935
3	4.518	44.338	39.844	2718.546	8475.889	3	5.559	41.167	27.100	1798.401	5775.545
4	446.475	164.864	37.770	192025.521	35831.313	4	424.704	164.766	38.074	126915.516	24082.468
5	1.699	70.856	4.356	192025.521	35831.313	5	1.730	70.874	4.334	126915.516	24082.468
6	656.116	0.406	0.000	192145.520	35993.313	6	757.623	0.406	0.000	127035.515	24244.468
7	7403.251	0.000	0.154	192626.248	36922.978	7	8842.851	0.000	0.580	127460.388	25033.575
8	25483.282	3.111	45.000	192993.248	36970.978	8	27050.434	3.111	45.000	127827.388	25081.575
9	0.000	35.108	165.231	317.531	112.791	9	0.000	94.856	220.499	65423.645	11945.925
10	11.830	1.219	0.000	0.000	0.000	10	6.905	60.967	0.000	0.000	0.000
11	330.000	38.219	210.231	0.000	0.000	11	330.000	97.967	265.498	0.000	0.000
12	0.783	2.899	3.704	0.000	313983.223	12	0.922	3.635	3.944	0.000	236927.953
13	0.604		0.231		181664.973	13	0.942		55.500		32884371.250
1	5.000	373.767	77.771	451.538	-0.014	1	175.000	445.857	80.066	525.923	33.972
2	191301.801	38.399	40.243	224.731	483.348	2	223365.748	39.213	28.713	169.018	379.614
3	4.806	41.316	39.603	2706.385	8440.314	3	5.569	42.282	28.197	1641.079	5312.596
4	423.667	164.609	37.770	191289.672	35676.829	4	424.712	164.766	38.133	115775.021	22089.906
5	1.699	70.903	4.356	191289.672	35676.829	5	1.731	70.874	4.333	115775.021	22089.906
6	661.693	0.406	0.000	191409.672	35838.829	6	758.367	0.406	0.000	115895.021	22251.905
7	7965.650	0.000	0.257	191889.768	36766.645	7	8896.041	0.000	0.580	116310.337	23017.176
8	25769.489	3.111	45.000	192256.768	36814.645	8	27071.675	3.111	45.000	116677.337	23065.175
9	0.000	35.921	165.643	1053.199	268.712	9	0.000	105.017	234.998	76563.534	13948.825
10	11.875	2.032	0.000	0.000	0.000	10	6.012	71.128	0.000	0.000	0.000
11	330.000	39.032	210.643	0.000	0.000	11	330.000	108.128	279.998	0.000	0.000
12	0.831	3.114	3.746	0.000	313090.416	12	0.922	3.638	3.946	0.000	223761.512
13	0.611		0.643		562850.875	13	0.998		70.000		38466083.000
1	10.000	444.280	81.204	525.484	33.832	1	200.000	445.288	80.156	525.444	33.972
2	223563.051	36.342	39.503	221.877	480.321	2	223212.951	37.930	30.917	162.920	364.328
3	5.471	39.061	38.865	2677.703	8349.119	3	5.555	41.169	30.414	1483.972	4850.706
4	425.442	164.637	37.770	189709.170	35280.229	4	424.808	164.781	38.238	104645.505	20097.271
5	1.729	70.898	4.356	189709.170	35280.229	5	1.730	70.871	4.329	104645.505	20097.271
6	759.917	0.406	0.000	189329.148	35442.229	6	758.010	0.406	0.000	104765.504	20259.271
7	8896.615	0.000	0.360	189807.480	36365.300	7	8893.487	0.000	0.580	105171.273	21000.703
8	27056.903	3.111	45.000	190174.480	36413.300	8	27077.923	3.111	45.000	105538.273	21048.703
9	0.000	37.953	167.340	3133.453	668.359	9	0.000	115.170	249.498	87692.437	15950.797
10	11.766	4.064	0.000	0.000	0.000	10	5.125	81.289	0.000	0.000	0.000
11	330.000	41.064	212.340	0.000	0.000	11	330.000	118.289	294.498	0.000	0.000
12	0.919	3.636	3.957	0.000	310604.777	12	0.921	3.635	3.946	0.000	210604.975
13	0.720		2.340		1614558.047	13	1.060		84.500		44043681.500
1	25.000	443.846	80.910	524.757	33.990	1	225.000	445.813	80.394	526.207	33.972
2	223194.117	35.289	36.441	214.436	471.125	2	223580.605	39.026	30.460	156.817	348.965
3	5.486	37.955	35.819	2583.516	8078.025	3	5.545	42.455	29.971	1326.732	4387.202
4	425.329	164.672	37.836	182556.197	34074.305	4	424.891	164.812	38.289	93503.661	18103.214
5	1.729	70.891	4.351	182556.197	34074.305	5	1.730	70.866	4.327	93503.661	18103.214
6	758.619	0.406	0.000	182676.195	34236.305	6	759.251	0.406	0.000	93623.660	18265.214
7	8891.977	0.000	0.361	183148.801	35144.949	7	8899.169	0.000	0.370	94019.872	18982.790
8	27039.201	3.111	45.000	183515.801	35192.949	8	27102.427	3.111	45.000	94386.872	19030.790
9	0.000	44.050	172.752	9786.037	1883.298	9	0.000	125.339	260.953	98833.677	17957.255
10	11.271	10.161	0.000	0.000	0.000	10	4.235	91.451	0.000	0.000	0.000
11	330.000	47.161	217.752	0.000	0.000	11	330.000	128.450	305.952	0.000	0.000
12	0.919	3.631	3.951	0.000	302727.750	12	0.922	3.641	3.947	0.000	197436.652
13	0.737		7.752		4961342.375	13	1.132		95.954		49629124.530
1	50.000	445.015	80.654	525.668	33.827	1	250.000	445.354	80.212	525.565	33.905
2	223458.023	37.804	32.342	204.315	456.118	2	223279.420	37.740	29.030	150.717	333.679
3	5.518	40.429	31.739	2426.811	7619.764	3	5.552	41.381	28.568	1169.593	3926.493
4	425.093	164.687	37.879	171449.845	32069.538	4	424.937	164.828	38.395	82374.181	16111.371
5	1.729	70.888	4.346	171449.846	32069.538	5	1.730	70.863	4.321	82374.181	16111.371
6	759.144	0.406	0.000	171569.844	32231.537	6	758.241	0.406	0.000	82494.180	16273.371
7	8896.500	0.000	0.363	172032.922	33116.198	7	8895.010	0.000	0.370	82880.844	16967.117
8	27052.888	3.111	45.000	172399.922	33164.198	8	27095.197	3.111	45.000	83247.844	17015.117
9	0.000	54.211	181.809	20891.754	3902.993	9	0.000	135.500	270.202	109962.544	19963.678
10	10.424	20.322	0.000	0.000	0.000	10	3.345	101.612	0.000	0.000	0.000
11	330.000	57.322	226.809	0.000	0.000	11	330.000	138.611	315.202	0.000	0.000
12	0.921	3.637	3.950	0.000	289583.117	12	0.922	3.637	3.943	0.000	184281.961
13	0.772		16.809		10542538.750	13	1.212		105.204		55209877.030

TABLE AP 2-1 (Sheet 2 of 2)
ENGINE PERFORMANCE PROGRAM (AA89)

1	275.000	445.701	80.154	525.855	33.905	1	375.000	365.407	74.308	439.715	-9.033
2	223371.191	38.333	28.393	144.514	318.318	2	188845.416	38.527	36.901	115.818	257.922
3	5.561	42.212	27.961	1012.343	3463.541	3	4.917	43.407	36.646	404.119	1629.239
4	424.777	164.859	38.477	71234.775	14120.517	4	429.473	165.141	39.115	28163.307	6260.673
5	1.730	70.857	4.317	71234.775	14120.517	5	1.692	70.829	4.296	28163.307	6260.673
6	758.448	0.406	0.000	71354.774	14282.517	6	655.837	0.406	0.000	28283.302	6422.673
7	8896.638	0.000	0.370	71731.883	14952.447	7	7919.495	0.000	1.078	28623.462	6998.572
8	27100.493	3.111	45.000	72098.883	15000.447	8	25267.374	3.111	45.000	28993.462	7046.572
9	0.000	145.661	279.452	121101.344	21969.099	9	0.000	186.305	375.682	164169.121	29826.743
10	2.449	111.773	0.000	0.000	0.030	10	-0.635	152.417	0.000	0.000	0.000
11	330.000	148.772	324.452	0.000	0.000	11	330.000	189.416	420.682	0.000	0.030
12	0.923	3.639	3.943	0.000	171118.328	12	0.837	3.046	3.639	0.000	120055.033
13	1.305		114.454		60793722.000	13	1.573		210.685		82449992.000
1	300.000	445.659	80.064	525.722	33.905	1	400.000	351.826	73.359	425.185	-16.235
2	223292.471	38.092	27.913	137.951	302.990	2	183036.016	37.843	37.190	107.902	243.732
3	5.566	42.231	27.514	855.082	3001.554	3	4.796	42.849	36.971	277.880	1195.494
4	424.734	164.922	38.605	60091.491	12131.519	4	430.485	165.219	39.301	19229.110	4411.882
5	1.730	70.846	4.311	60091.491	12131.519	5	1.684	70.828	4.289	19229.110	4411.882
6	758.139	0.406	0.000	60211.491	12293.519	6	638.599	0.406	0.000	19349.110	4573.882
7	8895.913	0.000	0.370	60579.040	12939.653	7	7757.109	0.000	1.067	19681.606	5127.663
8	27117.616	3.111	45.000	60946.040	12987.653	8	24963.939	3.111	45.000	20048.606	5175.663
9	0.000	155.822	288.702	132244.025	23972.663	9	0.000	196.466	402.424	173100.814	31670.999
10	1.566	121.934	0.000	0.000	0.000	10	-0.758	162.578	0.000	0.000	0.000
11	330.000	158.933	333.701	0.000	0.000	11	330.000	199.577	447.424	0.000	0.030
12	0.923	3.638	3.941	0.000	157952.691	12	0.822	2.947	3.585	0.000	109243.259
13	1.414		123.704		66377741.500	13	1.675		237.427		87084421.000
1	325.000	445.140	79.249	524.389	33.972	1	425.000	349.017	73.235	422.252	-17.676
2	222518.305	36.809	31.459	130.933	287.748	2	181884.922	38.194	39.687	98.393	228.227
3	5.617	41.217	31.125	697.890	2537.510	3	4.766	43.262	39.500	154.454	763.842
4	424.338	164.986	38.738	48959.514	10146.079	4	430.750	165.422	39.631	10500.777	2576.563
5	1.731	70.839	4.308	48959.514	10146.079	5	1.682	70.868	4.281	10500.777	2576.563
6	755.233	0.406	0.000	49079.514	10308.079	6	635.210	0.406	0.000	10620.777	2738.563
7	8884.235	0.000	1.187	49437.513	10930.460	7	7725.162	0.000	1.064	10945.785	3270.387
8	27097.976	3.111	45.000	49804.513	10978.460	8	24939.509	3.111	45.000	11312.785	3318.387
9	0.000	165.983	318.011	143375.391	25952.525	9	0.000	206.627	429.057	181826.475	33501.552
10	0.640	132.095	0.000	0.000	0.030	10	-0.809	172.739	0.000	0.000	0.000
11	330.000	169.094	363.011	0.000	0.030	11	330.000	209.738	474.057	0.000	0.030
12	0.920	3.626	3.941	0.000	144801.973	12	0.819	2.927	3.575	0.000	98650.172
13	1.537		153.014		71940697.000	13	1.844		264.061		91631341.000
1	350.000	432.169	78.561	510.729	13.561	1	442.869	344.919	72.899	417.818	-19.847
2	217119.363	38.792	34.638	123.285	272.518	2	180097.877	38.265	41.195	89.154	213.854
3	5.501	43.509	34.365	541.454	2073.699	3	4.731	43.173	41.022	86.851	455.656
4	425.116	165.047	38.926	37884.096	8160.049	4	431.044	165.765	40.068	4295.948	1269.095
5	1.725	70.833	4.302	37884.096	8160.049	5	1.680	70.838	4.273	4295.948	1269.095
6	739.379	0.406	0.000	38004.096	8322.049	6	629.825	0.406	0.000	4415.948	1431.095
7	8723.832	0.000	1.180	38352.594	8920.670	7	7679.404	0.000	1.061	4735.633	1947.277
8	26821.974	3.111	45.000	38719.594	8968.670	8	24889.786	3.111	45.000	5102.633	1995.277
9	0.000	176.144	347.663	154450.148	27932.663	9	0.000	213.881	448.018	188029.373	34805.701
10	-0.235	142.256	0.000	0.000	0.000	10	-0.839	179.993	0.000	0.000	0.030
11	330.000	179.255	392.663	0.000	0.000	11	330.000	216.992	493.018	0.000	0.000
12	0.907	3.533	3.894	0.000	131707.254	12	0.814	2.896	3.557	0.000	91116.910
13	1.648		182.666		77482350.000	13	1.977		283.021		94865488.000

1. ENGINE PERFORMANCE PROGRAM (F823)

This appendix contains engine performance determination and reconstruction of the S-IVB-202 stage flight, using computer program F823 (table AP 3-1). This program operates directly on measured engine functional parameters from the beginning of the start transients to the end of the cutoff transients, and is used for functional evaluation, evaluation of the systems, and the determination of the performance profiles. A discussion and a graphical presentation of the performance values are given in section 8.

The following procedures and assumptions were used to generate the printout:

a. The computation interval was 0.1 sec.

b. Measurements of thrust chamber pressure, gas generator pressure, LH2 pump discharge temperature, LH2 injection temperature, and LH2 turbine inlet temperature were obtained from magnetic tape.

c. Obvious instrumentation errors and noise were eliminated.

1.1 Digital Data Abbreviations

LOX CONST	LOX consumption (lbm)
FUEL CONST	LH2 consumption (lbm)
THRUST 1	Thrust chamber thrust (lbf)
THRUST 2	Gas generator thrust (lbf)
TOT. THRUST	J-2 engine thrust (lbf)
AVG. THRUST	Average J-2 engine thrust from 90 percent thrust to the particular time thereafter (lbf)
MIX. RAT. 1	Thrust chamber mixture ratio
MIX. RAT. 2	Gas generator mixture ratio
OA M. R.	J-2 engine mixture ratio
AVG. M. R.	Average J-2 engine mixture ratio from 90 percent thrust to the particular time thereafter
I SUB SP 1	Thrust chamber specific impulse (sec)
I SUB SP 2	Gas generator specific impulse (sec)

OA ISP	J-2 engine specific impulse (sec)
AVG ISP	Average J-2 engine specific impulse from 90 percent thrust to the particular time thereafter (sec)
WDOT O 1	Thrust chamber LOX flowrate (lbm/sec)
WDOT O 2	Gas generator LOX flowrate (lbm/sec)
TOT. WDOT O	Average J-2 engine LOX flowrate (defined similar to avg thrust) (lbm/sec)
WDOT F 1	Thrust chamber LH2 flowrate (lbm/sec)
WDOT F 2	Gas generator LH2 flowrate (lbm/sec)
TOT. WDOT F	J-2 engine LH2 flowrate (lbm/sec)
AVG. WDOT F	Average J-2 engine LH2 flowrate (defined similar to avg thrust) (lbm/sec)
WDOT T 1	Thrust chamber total flowrate (lbm/sec)
WDOT T 2	Gas generator total flowrate (lbm/sec)
TOT. WDOT T	J-2 engine LH2 flowrate (lbm/sec)
AVG. WDOT T	Average J-2 engine total flowrate (defined similar to avg thrust) (lbm/sec)

TABLE AP 3-1 (Sheet 1 of 2)
ENGINE PERFORMANCE PROGRAM (F823)

TIME

	A	B	C	D	E	F
1	T/C THRUST	T/C ISP	T/C W DOT T	T/C W DOT O	T/C W DOT F	T/C MR
2	RHO LOX	RHO LH2	G/G W DOT T	G/G W DOT O	G/G W DOT F	G/G MR
3	J-2 THRUST	J-2 ISP	J-2 W DOT T	J-2 W DOT O	J-2 W DOT F	J-2 MR
4	AVG. J2 F	AVG. J2 ISP	AVG. J2 DWT	AVG. J2 DWO	AVG. J2 DWF	AVG. J2 MR
5	LOX CONS.	LOX O/B	LOX IN TK	LH2 CONS.	LH2 3/B	LH2 IN TK

TOTAL IMPULSE

TIME = -0.

	A	B	C	D	E	F
1	1.0968E 03	8.5419E 03	1.2840E-01	7.8426E-02	4.9978E-02	1.5692E 00
2	6.4456E 01	4.0099E 00	0.	-0.	0.	-3.7124E-02
3	1.0968E 03	8.5419E 03	1.2840E-01	7.8426E-02	4.9978E-02	1.5692E 00
4	0.	0.	0.	0.	0.	0.
5	-0.	-0.	1.9331E 05	-0.	-0.	3.7084E 04

TOTAL IMPULSE = -0.

TIME = 1.0000

	A	B	C	D	E	F
1	8.0399E 02	8.4600E 03	9.5035E-02	5.5039E-02	3.9995E-02	1.3761E 00
2	6.2518E 01	3.6843E 00	1.7951E 00	-8.7936E-02	1.8830E 00	-4.6699E-02
3	8.0399E 02	4.2536E 02	1.8901E 00	-3.2897E-02	1.9230E 00	-1.7107E-02
4	0.	0.	0.	0.	0.	0.
5	5.8264E 01	5.8671E 01	1.9325E 05	4.1597E 01	4.1649E 01	3.7042E 04

TOTAL IMPULSE = 4.3228E 04

TIME = 2.0000

	A	B	C	D	E	F
1	1.8679E 04	8.6147E 03	2.1682E 00	1.3577E 00	8.1053E-01	1.6751E 00
2	7.0725E 01	4.3718E 00	2.9092E 00	4.9894E-01	2.4103E 00	2.0700E-01
3	1.8679E 04	3.6788E 03	5.0775E 00	1.8567E 00	3.2208E 00	5.7646E-01
4	0.	0.	0.	0.	0.	0.
5	5.9144E 01	5.9957E 01	1.9325E 05	4.4216E 01	4.4411E 01	3.7040E 04

TOTAL IMPULSE = 4.8242E 04

TIME = 3.0000

	A	B	C	D	E	F
1	1.4717E 05	4.5005E 02	3.2701E 02	2.6295E 02	6.4060E 01	4.1048E 00
2	7.0797E 01	4.3774E 00	6.2944E 00	1.9660E 00	4.3284E 00	4.5420E-01
3	1.4717E 05	4.4155E 02	3.3331E 02	2.6492E 02	6.8389E 01	3.8737E 00
4	0.	0.	0.	0.	0.	0.
5	2.0583E 02	2.0705E 02	1.9310E 05	9.4878E 01	9.5303E 01	3.6989E 04

TOTAL IMPULSE = 1.4376E 05

TIME = 3.4899

	A	B	C	D	E	F
1	1.7877E 05	4.3338E 02	4.1250E 02	3.3309E 02	7.9404E 01	4.1949E 00
2	7.0779E 01	4.3770E 00	6.8106E 00	2.5253E 00	4.2853E 00	5.8930E-01
3	1.7877E 05	4.2634E 02	4.1931E 02	3.3562E 02	8.3689E 01	4.0103E 00
4	0.	0.	0.	0.	0.	0.
5	3.5627E 02	3.5768E 02	1.9295E 05	1.3281E 02	1.3337E 02	3.6951E 04

TOTAL IMPULSE = 2.2507E 05

TIME = 5.0000

	A	B	C	D	E	F
1	1.9151E 05	4.3495E 02	4.4030E 02	3.6612E 02	7.4187E 01	4.9350E 00
2	7.0796E 01	4.3773E 00	6.6950E 00	2.7834E 00	3.9116E 00	7.1158E-01
3	1.9151E 05	4.2843E 02	4.4700E 02	3.6890E 02	7.8099E 01	4.7235E 00
4	1.9117E 05	4.2660E 02	4.4813E 02	3.6672E 02	8.1408E 01	4.5047E 00
5	9.1004E 02	9.1207E 02	1.9246E 05	2.5575E 02	2.5675E 02	3.6827E 04

TOTAL IMPULSE = 5.1375E 05

TIME = 10.0000

	A	B	C	D	E	F
1	2.2224E 05	4.3018E 02	5.1662E 02	4.3887E 02	7.7752E 01	5.6444E 00
2	7.0788E 01	4.3769E 00	7.3591E 00	3.3344E 00	4.0247E 00	8.2848E-01
3	2.2224E 05	4.2414E 02	5.2398E 02	4.4220E 02	8.1777E 01	5.4074E 00
4	2.0459E 05	4.2615E 02	4.8008E 02	3.9986E 02	8.0218E 01	4.9846E 00
5	2.9594E 03	2.9634E 03	1.9035E 05	8.5504E 02	8.5770E 02	3.6426E 04

TOTAL IMPULSE = 1.5569E 06

TIME = 20.0000

	A	B	C	D	E	F
1	2.2477E 05	4.3018E 02	5.2224E 02	4.4524E 02	7.7017E 01	5.7611E 00
2	7.0783E 01	4.3741E 00	7.4274E 00	3.4142E 00	4.0134E 00	8.5071E-01
3	2.2477E 05	4.2435E 02	5.2969E 02	4.4866E 02	8.1030E 01	5.5369E 00
4	2.1607E 05	4.2504E 02	5.0835E 02	4.2760E 02	8.0753E 01	5.2932E 00
5	7.4160E 03	7.4241E 03	1.8589E 05	1.4660E 03	1.4723E 03	3.5612E 04

TOTAL IMPULSE = 3.7924E 06

TIME = 40.0000

	A	B	C	D	E	F
1	2.2534E 05	4.3073E 02	5.2316E 02	4.4688E 02	7.6277E 01	5.8586E 00
2	7.0779E 01	4.3713E 00	7.4538E 00	3.4461E 00	4.0076E 00	8.5990E-01
3	2.2534E 05	4.2468E 02	5.3061E 02	4.5032E 02	8.0285E 01	5.6091E 00
4	2.2089E 05	4.2482E 02	5.1996E 02	4.3941E 02	8.0551E 01	5.4551E 00
5	1.6399E 04	1.6415E 04	1.7690E 05	3.0737E 03	3.0872E 03	3.3997E 04

TOTAL IMPULSE = 8.2899E 06

TIME = 60.0000

	A	B	C	D	E	F
1	2.2567E 05	4.3065E 02	5.2401E 02	4.4762E 02	7.6392E 01	5.8595E 00
2	7.0782E 01	4.3704E 00	7.4795E 00	3.4524E 00	4.0271E 00	8.5729E-01
3	2.2567E 05	4.2459E 02	5.3149E 02	4.5107E 02	8.0419E 01	5.6090E 00
4	2.2254E 05	4.2478E 02	5.2391E 02	4.4363E 02	8.0478E 01	5.5101E 00
5	2.5413E 04	2.5439E 04	1.6787E 05	4.6805E 03	4.7011E 03	3.2363E 04

TOTAL IMPULSE = 1.2801E 07

TIME = 80.0000

	A	B	C	D	E	F
1	2.2583E 05	4.3058E 02	5.2448E 02	4.4790E 02	7.6493E 01	5.8565E 00
2	7.0705E 01	4.3680E 00	7.5069E 00	3.4725E 00	4.0344E 00	8.6071E-01
3	2.2583E 05	4.2451E 02	5.3190E 02	4.5146E 02	8.0520E 01	5.6062E 00
4	2.2327E 05	4.2474E 02	5.2566E 02	4.4524E 02	8.0422E 01	5.5363E 00
5	3.4422E 04	3.4454E 04	1.5886E 05	6.2859E 03	6.3138E 03	3.0770E 04

TOTAL IMPULSE = 1.7307E 07

TIME = 100.0000

	A	B	C	D	E	F
1	2.2440E 05	4.3121E 02	5.2039E 02	4.4491E 02	7.5485E 01	5.9940E 00
2	7.0780E 01	4.3642E 00	7.4323E 00	3.4387E 00	3.9935E 00	8.6108E-01
3	2.2440E 05	4.2514E 02	5.2702E 02	4.4834E 02	7.9478E 01	5.6411E 00
4	2.2372E 05	4.2474E 02	5.2672E 02	4.4637E 02	8.0351E 01	5.5553E 00
5	4.3636E 04	4.3676E 04	1.4984E 05	7.8075E 03	7.9226E 03	2.9161E 04

TOTAL IMPULSE = 2.1817E 07

TIME = 120.0000

	A	B	C	D	E	F
1	2.2571E 05	4.3102E 02	5.2365E 02	4.4798E 02	7.5471E 01	5.9202E 00
2	7.0775E 01	4.3621E 00	7.4651E 00	3.4579E 00	4.0072E 00	8.6292E-01
3	2.2571E 05	4.2496E 02	5.3112E 02	4.5144E 02	7.9670E 01	5.6658E 00
4	2.2404E 05	4.2476E 02	5.2746E 02	4.4718E 02	8.0278E 01	5.5704E 00
5	5.2457E 04	5.2506E 04	1.4081E 05	9.4060E 03	9.5204E 03	2.7556E 04

TOTAL IMPULSE = 2.6328E 07

TIME = 140.0000

	A	B	C	D	E	F
1	2.2541E 05	4.3068E 02	5.2338E 02	4.4702E 02	7.6357E 01	5.8543E 00
2	7.0774E 01	4.3591E 00	7.4454E 00	3.4511E 00	3.9943E 00	8.6402E-01
3	2.2541E 05	4.2464E 02	5.3082E 02	4.5047E 02	8.0352E 01	5.6063E 00
4	2.2420E 05	4.2478E 02	5.2780E 02	4.4758E 02	8.0222E 01	5.5792E 00
5	6.1455E 04	6.1512E 04	1.3180E 05	1.1084E 04	1.1134E 04	2.5950E 04

TOTAL IMPULSE = 3.0830E 07

TIME = 160.0000

	A	B	C	D	E	F
1	2.2513E 05	4.3103E 02	5.2231E 02	4.4658E 02	7.5730E 01	5.8970E 00
2	7.0771E 01	4.3552E 00	7.4583E 00	3.4650E 00	3.9933E 00	8.6770E-01
3	2.2513E 05	4.2496E 02	5.2977E 02	4.5005E 02	7.9724E 01	5.6451E 00
4	2.2436E 05	4.2479E 02	5.2816E 02	4.4798E 02	8.0180E 01	5.5871E 00
5	7.0469E 04	7.0534E 04	1.2278E 05	1.2682E 04	1.2743E 04	2.4341E 04

TOTAL IMPULSE = 3.5339E 07

TIME = 180.0000

	A	B	C	D	E	F
1	2.2376E 05	4.3135E 02	5.1875E 02	4.4343E 02	7.5316E 01	5.8877E 00
2	7.0769E 01	4.3545E 00	7.4157E 00	3.4366E 00	3.9791E 00	8.6365E-01
3	2.2376E 05	4.2527E 02	5.2617E 02	4.4687E 02	7.9295E 01	5.6355E 00
4	2.2438E 05	4.2482E 02	5.2818E 02	4.4807E 02	8.0114E 01	5.5929E 00
5	7.9444E 04	7.9518E 04	1.1379E 05	1.4274E 04	1.4346E 04	2.2738E 04

TOTAL IMPULSE = 3.9831E 07

TIME = 200.0000

	A	B	C	D	E	F
1	2.2534E 05	4.3103E 02	5.2279E 02	4.4709E 02	7.5701E 01	5.9060E 00
2	7.0767E 01	4.3527E 00	7.4721E 00	3.4700E 00	4.0021E 00	8.6703E-01
3	2.2534E 05	4.2496E 02	5.3027E 02	4.5056E 02	7.9703E 01	5.6530E 00
4	2.2442E 05	4.2484E 02	5.2826E 02	4.4818E 02	8.0077E 01	5.5969E 00
5	8.8428E 04	8.8510E 04	1.0480E 05	1.5869E 04	1.5953E 04	2.1131E 04

TOTAL IMPULSE = 4.4326E 07

TIME = 220.0000

	A	B	C	D	E	F
1	2.2578E 05	4.3091E 02	5.2396E 02	4.4808E 02	7.5874E 01	5.9057E 00
2	7.0761E 01	4.3504E 00	7.4880E 00	3.4677E 00	4.0203E 00	8.6255E-01
3	2.2578E 05	4.2484E 02	5.3145E 02	4.5155E 02	7.9894E 01	5.6519E 00
4	2.2452E 05	4.2485E 02	5.2846E 02	4.4842E 02	8.0036E 01	5.6028E 00
5	9.7444E 04	9.7534E 04	9.5778E 04	1.7461E 04	1.7555E 04	1.9529E 04

TOTAL IMPULSE = 4.8835E 07

TIME = 240.0000

	A	B	C	D	E	F
1	2.2506E 05	4.3109E 02	5.2207E 02	4.4643E 02	7.5639E 01	5.9022E 00
2	7.0756E 01	4.3465E 00	7.4765E 00	3.4667E 00	4.0117E 00	8.6365E-01
3	2.2506E 05	4.2500E 02	5.2955E 02	4.4990E 02	7.9651E 01	5.6484E 00
4	2.2453E 05	4.2487E 02	5.2857E 02	4.4858E 02	7.9998E 01	5.6073E 00
5	1.0645E 05	1.0655E 05	8.6766E 04	1.9053E 04	1.9154E 04	1.7930E 04

TOTAL IMPULSE = 5.3339E 07

TIME = 260.0000

	A	B	C	D	E	F
1	2.2626E 05	4.3099E 02	5.2497E 02	4.4932E 02	7.5657E 01	5.9389E 00
2	7.0753E 01	4.3444E 00	7.4561E 00	3.4710E 00	3.9851E 00	8.7101E-01
3	2.2626E 05	4.2495E 02	5.3243E 02	4.5279E 02	7.9642E 01	5.6853E 00
4	2.2463E 05	4.2488E 02	5.2869E 02	4.4873E 02	7.9960E 01	5.6120E 00
5	1.1546E 05	1.1557E 05	7.7745E 04	2.0643E 04	2.0751E 04	1.6333E 04

TOTAL IMPULSE = 5.7846E 07

TIME = 280.0000

	A	B	C	D	E	F
1	2.2492E 05	4.3121E 02	5.2160E 02	4.4819E 02	7.5415E 01	5.9164E 00
2	7.0752E 01	4.3405E 00	7.4576E 00	3.4591E 00	3.9985E 00	8.6510E-01
3	2.2492E 05	4.2513E 02	5.2906E 02	4.4965E 02	7.9414E 01	5.6621E 00
4	2.2471E 05	4.2489E 02	5.2686E 02	4.4692E 02	7.9939E 01	5.6158E 00
5	1.2449E 05	1.2460E 05	6.8710E 04	2.2237E 04	2.2352E 04	1.4732E 04

TOTAL IMPULSE = 6.2359E 07

TABLE AP 3-1 (Sheet 2 of 2)
ENGINE PERFORMANCE PROGRAM (F823)

TIME = 300.0000

	A	B	C	D	E	F
1	2.2461E 05	4.3159E 02	5.2046E 02	4.4567E 02	7.4816E 01	5.9569E 00
2	7.0744E 01	4.3356E 00	7.4173E 00	3.4383E 00	3.9749E 00	8.6529E-01
3	2.2461E 05	4.2549E 02	5.2709E 02	4.4910E 02	7.8790E 01	5.7000E 00
4	2.2473E 05	4.2490E 02	5.2889E 02	4.4899E 02	7.9904E 01	5.6191E 00
5	1.3349E 05	1.3361E 05	5.9703E 04	2.3825E 04	2.3948E 04	1.1136E 04

TOTAL IMPULSE = 6.6860E 07

TIME = 320.0000

	A	B	C	D	E	F
1	2.2409E 05	4.3155E 02	5.1927E 02	4.4438E 02	7.4898E 01	5.9331E 00
2	7.0735E 01	4.3332E 00	7.4617E 00	3.4652E 00	3.9985E 00	8.6704E-01
3	2.2409E 05	4.2543E 02	5.2674E 02	4.4784E 02	7.8895E 01	5.6765E 00
4	2.2468E 05	4.2494E 02	5.2875E 02	4.4891E 02	7.9443E 01	5.6223E 00
5	1.4244E 05	1.4255E 05	5.0742E 04	2.5404E 04	2.5550E 04	1.1534E 04

TOTAL IMPULSE = 7.1340E 07

TIME = 340.0000

	A	B	C	D	E	F
1	2.2476E 05	4.3154E 02	5.2082E 02	4.4601E 02	7.4811E 01	5.9619E 00
2	7.0727E 01	4.3252E 00	7.4373E 00	3.4562E 00	3.9811E 00	8.6816E-01
3	2.2476E 05	4.2547E 02	5.2826E 02	4.4947E 02	7.8792E 01	5.7045E 00
4	2.2469E 05	4.2496E 02	5.2872E 02	4.4894E 02	7.9769E 01	5.6265E 00
5	1.5143E 05	1.5157E 05	4.1746E 04	2.6983E 04	2.7152E 04	9.9321E 03

TOTAL IMPULSE = 7.5835E 07

TIME = 360.0000

	A	B	C	D	E	F
1	2.0297E 05	4.3486E 02	4.6675E 02	3.9450E 02	7.2250E 01	5.4602E 00
2	7.6719E 01	4.3242E 00	6.9387E 00	3.1067E 00	3.8320E 00	8.1072E-01
3	2.0297E 05	4.2849E 02	4.7368E 02	3.9760E 02	7.6082E 01	5.2260E 00
4	2.2430E 05	4.2504E 02	5.2771E 02	4.4803E 02	7.9687E 01	5.6223E 00
5	1.6008E 05	1.6023E 05	3.3083E 04	2.8542E 04	2.8735E 04	8.3492E 03

TOTAL IMPULSE = 8.0190E 07

TIME = 380.0000

	A	B	C	D	E	F
1	1.8715E 05	4.3918E 02	4.2614E 02	3.5708E 02	6.8257E 01	5.2431E 00
2	7.0707E 01	4.3189E 00	6.5208E 00	2.8039E 00	3.7169E 00	7.5435E-01
3	1.8715E 05	4.3256E 02	4.3266E 02	3.6068E 02	7.1974E 01	5.0113E 00
4	2.2261E 05	4.2531E 02	5.2342E 02	4.4406E 02	7.9355E 01	5.5959E 00
5	1.6759E 05	1.6770E 05	2.5602E 04	3.0011E 04	3.0225E 04	6.8500E 03

TOTAL IMPULSE = 8.4041E 07

TIME = 400.0000

	A	B	C	D	E	F
1	1.8420E 05	4.3954E 02	4.1908E 02	3.5075E 02	6.8330E 01	5.1331E 00
2	7.0694E 01	4.3116E 00	6.4001E 00	2.7602E 00	3.7199E 00	7.4200E-01
3	1.8420E 05	4.3285E 02	4.2556E 02	3.5351E 02	7.2050E 01	4.9064E 00
4	2.2074E 05	4.2562E 02	5.1863E 02	4.3955E 02	7.8955E 01	5.5666E 00
5	1.7468E 05	1.7484E 05	1.8469E 04	3.1449E 04	3.1605E 04	5.3992E 03

TOTAL IMPULSE = 8.7750E 07

TIME = 410.0000

	A	B	C	D	E	F
1	1.8302E 05	4.4002E 02	4.1593E 02	3.4808E 02	6.7858E 01	5.1294E 00
2	7.0680E 01	4.3076E 00	6.4449E 00	2.7410E 00	3.7039E 00	7.4002E-01
3	1.8302E 05	4.3331E 02	4.2238E 02	3.5002E 02	7.1562E 01	4.9022E 00
4	2.1902E 05	4.2577E 02	5.1628E 02	4.3748E 02	7.8802E 01	5.5517E 00
5	1.7820E 05	1.7836E 05	1.4949E 04	3.2166E 04	3.2413E 04	4.6712E 03

TOTAL IMPULSE = 8.9503E 07

TIME = 430.0000

	A	B	C	D	E	F
1	1.8213E 05	4.4022E 02	4.1372E 02	3.4596E 02	6.7753E 01	5.1063E 00
2	7.0652E 01	4.2965E 00	6.4639E 00	2.7490E 00	3.7149E 00	7.4001E-01
3	1.8213E 05	4.3345E 02	4.2018E 02	3.4871E 02	7.1460E 01	4.8793E 00
4	2.1809E 05	4.2606E 02	5.1187E 02	4.3341E 02	7.8464E 01	5.5236E 00
5	1.8521E 05	1.8538E 05	7.9290E 03	3.3590E 04	3.3866E 04	3.2101E 03

TOTAL IMPULSE = 9.3242E 07

TIME = 442.8490

	A	B	C	D	E	F
1	1.8299E 05	4.3931E 02	4.1653E 02	3.4758E 02	6.8954E 01	5.0408E 00
2	7.0600E 01	4.2807E 00	6.4369E 00	2.7289E 00	3.7090E 00	7.3596E-01
3	1.8299E 05	4.3262E 02	4.2297E 02	3.5031E 02	7.2662E 01	4.8211E 00
4	2.1704E 05	4.2623E 02	5.0921E 02	4.3094E 02	7.8274E 01	5.5055E 00
5	1.8969E 05	1.8987E 05	3.4389E 03	3.4523E 04	3.4804E 04	2.2797E 03

TOTAL IMPULSE = 9.5585E 07

1. FLOWMETER RECONSTRUCTION (G105)

This appendix contains engine performance using computer program G105 (table AP 4-1). This program operates directly on measured engine functional parameters from the beginning of the start transients, through steady-state, to the end of cutoff transients, and is used for functional evaluation of the systems such as determination of the profiles of thrust and flowrates. For a discussion of the performance values, see section 8 and associated plots.

1.1 Digital Data Abbreviations

Abbreviations appearing on the printout are defined as follows:

TIME	Time from engine start signal (sec)
THRUST	Engine total thrust (lbf)
EMR	Engine total mixture ratio (O/F)
ISP	Engine total specific impulse (sec)
WDOTO	Engine total oxidizer flowrate (lb/sec)
WDOTF	Engine total fuel flowrate (lb/sec)
WDOTT	Engine total propellant flowrate (lb/sec)
WO	Oxidizer mass on board (lbm)
WF	Fuel mass on board (lbm)
WT	Total propellant on board (lbm)

TABLE AP 4-1
FLOWMETER RECONSTRUCTION DATA (G105)

TIME WDOTF WDOTFP WDBO EMRTC	THRUST WDOTT WFP WDOTFGG ETACF	EMR WO WDOTFBO WFGG CSUBF	ISP WF WFBO WDOTOGG	WDOTO WT WDOTOBO WOGG
0.0000	0.0000	0.0000	0.0000	0.0000
0.5020	0.5020	193312.0000	37784.0000	230396.0000
0.0000	0.0000	0.0000	0.0000	0.4064
0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.9829	1.5447		
0.5000	0.0000	0.0000	0.0000	0.0000
1.0812	1.0812	193311.7949	37683.5909	230395.3868
0.0465	0.0116	0.0000	0.0000	0.4064
0.2032	0.6257	0.1564	0.3333	0.0833
0.0000	0.9829	1.5447		
1.0000	0.0000	0.0000	0.0000	0.0000
1.6670	1.6670	193311.5898	37682.8672	230394.4570
0.0930	0.0465	0.0000	0.0000	0.4064
0.4064	1.2514	0.6257	0.6667	0.3333
0.0000	0.9829	1.5447		
1.5000	1745.9455	0.0000	41.6652	0.0000
41.9243	41.9243	193311.2910	37075.2012	230386.4922
0.1395	0.1046	0.0000	0.0000	0.4064
0.6096	1.8771	1.4079	1.0000	0.7500
0.0000	0.9829	1.5465		
2.0000	18241.7273	3.4034	81.9248	172.1004
50.5639	222.6643	193247.9023	37051.2666	230299.1660
0.1860	0.1860	0.0000	0.0000	0.4064
0.4128	2.5029	2.5029	1.3333	1.3333
3.5531	1.0152	1.8155		
3.0000	148566.1172	4.5285	416.4450	292.2788
64.5418	356.8205	192967.4980	36996.0518	229993.5488
0.2600	0.4123	0.0000	0.0000	0.4064
1.2192	3.7543	5.6314	2.0000	3.0000
4.7753	1.0263	1.8651		
4.3000	165592.4492	3.9353	443.2452	297.8930
75.0980	373.5910	192911.3906	36974.5781	229885.9688
0.2708	0.4919	0.0000	0.0000	0.4064
1.1412	4.1297	6.8140	2.3960	3.6594
4.1289	1.0205	1.8432		
4.0000	192868.6875	4.5289	451.0090	350.2919
77.3403	427.6382	192677.7813	36920.7334	229598.5137
0.2960	0.6903	0.0000	0.0000	0.4064
1.6256	4.6700	9.7775	2.6967	5.5042
4.7436	1.0261	1.8649		
5.0000	191673.8457	4.7630	493.8808	365.1109
78.6552	441.7661	192315.0293	36843.0718	229158.0996
0.3020	0.9891	0.0000	0.0000	0.4064
2.0321	5.9300	13.8025	2.7700	8.2375
4.9823	1.0282	1.8724		
6.0000	193077.6875	4.8061	431.7041	370.2155
77.0299	447.7455	191945.5254	36765.8672	228711.3926
0.3100	1.2953	0.0000	0.0000	0.4064
2.4385	3.8900	17.7125	2.8300	11.0375
5.0230	1.0286	1.8736		
10.0000	222342.6270	5.4548	428.7407	438.3514
80.3604	518.7119	190271.6289	36448.3555	226719.9844
0.3500	2.6423	0.0000	0.0000	0.4064
4.2641	4.0100	33.7225	3.3300	23.6453
5.6977	1.0347	1.8929		
25.0000	224270.0156	5.6109	422.6425	450.2696
80.2497	520.5193	183567.1699	35238.4097	218805.5781
0.3594	8.0039	0.0000	0.0000	0.4064
10.1063	4.0100	93.8724	3.4325	74.9012
9.4610	1.0362	1.8971		
50.0000	225654.4648	5.5827	426.4456	448.8466
80.3999	525.2456	172310.1387	33224.1758	205534.3145
0.3600	17.0023	0.0000	0.0000	0.4064
20.3206	4.0100	194.1222	3.4450	160.7698
5.8307	1.0359	1.8963		
75.0000	225693.3379	5.5808	424.8275	449.8708
80.6100	530.4809	161054.7383	31204.8213	192259.5586
0.3625	26.0335	0.0000	0.0000	0.4064
30.4808	4.0087	294.3562	3.4494	246.9330
5.8279	1.0359	1.8963		
100.0000	224155.6992	5.5580	423.6993	448.3721
80.6722	526.0443	149812.3242	29182.4048	178994.7285
0.3633	35.1106	0.0000	0.0000	0.4064
40.5411	4.0075	394.5588	3.4500	333.4291
5.8035	1.0357	1.8956		

TIME WDOTF WDOTFP WDBO EMRTC	THRUST WDOTT WFP WDOTFGG ETACF	EMR WO WDOTFBO WFGG CSUBF	ISP WF WFBO WDOTOGG	WDOTO WT WDOTOBO WOGG
125.0000	224855.6426	5.5727	423.1620	450.5333
80.8463	531.3796	138555.4648	27159.1536	165714.6172
0.3638	44.1992	0.0000	0.0000	0.4064
50.8013	4.0062	494.7302	3.4690	419.8871
5.8182	1.0358	1.8960		
150.0000	225247.6573	5.5944	424.5009	450.1527
80.4649	530.6177	127298.1602	25134.8459	152433.0059
0.5730	55.4291	0.0000	0.0000	0.4064
60.9615	4.0050	594.8700	3.4700	506.3415
5.8421	1.0361	1.8966		
175.0000	224843.3691	5.5939	424.9439	448.8698
80.2432	529.1130	116049.5205	23110.2632	139159.7812
0.5730	69.7540	0.0000	0.0000	0.4064
71.1217	4.0037	694.9784	3.4480	592.7631
5.8424	1.0361	1.8966		
200.0000	225301.1250	5.6174	424.7610	450.2631
80.1554	530.4186	104798.6113	21085.3438	125883.9551
0.5730	84.0789	0.0000	0.0000	0.4064
81.2819	4.0025	795.0556	3.4700	679.2222
5.8671	1.0363	1.8972		
225.0000	224534.8301	5.5852	423.0968	450.1047
80.5890	530.6937	93546.3994	19060.3950	112606.7939
0.3638	65.4245	0.0000	0.0000	0.4064
91.4421	4.0012	895.1015	3.4600	765.7707
5.8318	1.0360	1.8963		
250.0000	225905.4277	5.5965	425.4668	450.4676
80.4914	530.9590	82278.9541	17038.5181	99317.4717
0.3636	104.5171	0.0000	0.0000	0.4064
101.6023	4.0000	995.1162	3.4600	852.2644
5.8439	1.0361	1.8967		
275.0000	224532.4102	5.6124	422.8435	450.7017
80.3042	531.0059	71003.8223	15015.1176	86018.9395
0.3633	113.6026	0.0000	0.0000	0.4064
111.7625	3.9900	1094.9895	3.4656	938.9440
5.8605	1.0362	1.8971		
300.0000	224465.8203	5.6125	422.3298	450.9959
80.3562	531.3521	59722.8413	12995.0146	72718.8553
0.3630	122.6810	0.0000	0.0000	0.4064
121.9227	3.9800	1194.6126	3.4600	1025.5125
5.8596	1.0367	1.8970		
325.0000	224159.1836	5.6365	421.9581	451.6158
80.1239	531.7357	48435.0081	10976.1636	59415.3716
1.1869	131.4677	0.0000	0.0000	0.4064
132.0928	3.9800	1294.1114	3.4586	1111.9149
5.8857	1.0364	1.8977		
350.0000	223344.3203	5.5202	426.4866	437.4112
79.2348	514.6500	37156.9629	8955.9534	46112.9160
1.1750	181.1134	0.0000	0.0000	0.4064
142.2429	3.9300	1393.4846	3.4000	1198.3737
5.7631	1.0353	1.8946		
375.0000	186251.3184	4.8702	429.1326	361.9499
74.7297	438.6787	27295.6689	7012.0036	34307.6724
1.0770	208.9901	0.0000	0.0000	0.4064
152.4028	3.7400	1489.0077	2.8300	1275.2969
5.0869	1.0292	1.8755		
400.0000	183776.5645	4.7609	430.6620	352.6570
74.0733	426.7303	18374.4517	5128.3167	23502.7683
1.0619	235.6849	0.0000	0.0000	0.4064
162.5627	3.7100	1582.2306	2.7650	1345.1324
4.9726	1.0281	1.8719		
425.0000	182617.5527	4.7683	429.6711	351.3359
73.6811	425.0170	5567.4011	3254.3233	12821.7246
1.0589	262.1586	0.0000	0.0000	0.4064
172.7227	3.7129	1675.2608	2.7494	1414.9373
4.9821	1.0282	1.8722		
442.8000	180389.2207	4.7116	429.2604	346.6574
73.5752	420.2326	3329.9751	1922.6787	5252.6538
1.0540	280.9454	0.0000	0.0000	0.4064
179.9566	3.7201	1741.4975	2.7400	1462.8927
4.9233	1.0277	1.8704		
442.8490	182325.3320	4.7284	432.2839	348.1445
73.6277	421.7722	3312.9320	1919.0204	5231.9524
1.0540	280.9971	0.0000	0.0000	0.4064
179.9765	3.7200	1741.6797	2.7400	1463.0263
4.9409	1.0279	1.8709		

1. ENGINE PERFORMANCE PROGRAM (PA49)

This appendix contains the digital printout of computer program PA49. Printout PA49 is a compilation of computer programs AA89, G105, and F823. These computer programs are the methods employed in the propulsion system performance reconstruction of the S-IVB-202 stage flight evaluation. The performance analysis and associated plots are presented in section 8.

Printout symbols are presented in table AP 5-1 and the digital printout is contained in table AP 5-2.

TABLE AP 5-1
PROGRAM PA49 PRINTOUT SYMBOLS

FSUB1	Stage thrust from AA89 (lbf)
WDOTT1	Total flowrate from AA89 (lbm/sec)
WDOTO1	Oxidizer flowrate from AA89 (lbm/sec)
WDOTF1	Fuel flowrate from AA89 (lbm/sec)
EMR 1	Engine mixture ratio from AA89
ISP 1	Specific impulse from AA89 (sec)
MSUBO1	Liquid oxidizer mass onboard from AA89 (lbm)
MSUBF1	Liquid fuel mass onboard from AA89 (lbm)
FSUB2	Stage thrust from G105 (lbf)
WDOTT2	Total flowrate from G105 (lbm/sec)
WDOTO2	Oxidizer flowrate from G105 (lbm/sec)
WDOTF2	Fuel flowrate from G105 (lbm/sec)
EMR 2	Engine mixture ratio from G105
ISP 2	Specific impulse from G105 (sec)
MSUBO2	Liquid oxidizer mass onboard from G105
MSUBF2	Liquid fuel mass onboard from G105 (lbm)
FSUB 3	Stage thrust from F823 (lbf)
WDOTT3	Total flowrate from F823 (lbm/sec)
WDOTO3	Oxidizer flowrate from F823 (lbm/sec)
WDOTF3	Fuel flowrate from F823 (lbm/sec)
EMR 3	Engine mixture from F823
ISP 3	Specific impulse from F823 (sec)
MSUBO3	Liquid oxidizer mass onboard from F823 (lbm)
MSUBF3	Liquid fuel mass onboard from F823 (lbm)
FSUB4	Predicted stage thrust (lbf)
WDOTT4	Predicted total flowrate (lbm/sec)
WDOTO4	Predicted oxidizer flowrate (lbm/sec)
WDOTF4	Predicted fuel flowrate (lbm/sec)
EMR 4	Predicted engine mixture ratio
ISP 4	Predicted specific impulse (sec)
MSUBO4	Predicted liquid oxidizer mass onboard (lbm)
MSUBF4	Predicted liquid fuel mass onboard (lbm)
THRUST	Composite stage thrust (lbf)
T FLOW	Composite total flowrate (lbm/sec)
O FLOW	Composite oxidizer flowrate (lbm/sec)
F FLOW	Composite fuel flowrate (lbm/sec)
EMR	Composite engine mixture ratio
ISP	Composite specific impulse (sec)
O MASS	Composite liquid oxidizer mass onboard (lbm)
F MASS	Composite liquid fuel mass onboard (lbm)

TABLE AP 5-2 (Sheet 1 of 2)
ENGINE PERFORMANCE PROGRAM (PA49)

TIME									
FSUB 1	FSUB 2	FSUB 3	FSUB 4	FMDUST	125.000				
WDOT1	WDOT12	WDOT13	WDOT14	T FLOW	223743.791	224859.643	224941.789	223658.641	224515.072
WDOT01	WDOT02	WDOT03	WDOT04	D FLOW	526.620	531.380	529.458	527.141	529.162
WDOTF1	WDOTF2	WDOTF3	WDOTF4	F FLOW	446.202	450.533	449.448	446.899	448.728
EMB 1	EMB 2	EMB 3	EMB 4	*EMB*	80.417	80.866	80.049	80.242	80.434
ISP 1	ISP 2	ISP 3	ISP 4	*ISP*	5.569	5.593	5.615	5.569	5.579
MSUB01	MSUB02	MSUB03	MSUB04	D MASS	424.008	424.167	424.879	424.286	424.286
MSUBF1	MSUBF2	MSUBF3	MSUBF4	F MASS	138967.229	138555.465	138550.092	138692.483	138690.928
					27097.519	27159.154	27154.009	27095.553	27136.094
0.000					150.000				
0.000	0.900	1996.810	0.000	365.603	223129.965	225247.697	225367.320	223913.209	224501.658
0.000	0.502	0.128	0.000	0.210	525.178	530.618	530.319	527.651	528.772
0.000	0.900	0.078	0.000	0.026	445.404	450.153	450.566	447.219	448.708
0.000	0.502	0.050	0.000	0.184	79.975	80.465	79.753	80.432	80.064
0.000	0.000	1.569	0.000	0.523	5.569	5.594	5.650	5.560	5.604
0.000	0.900	8541.867	0.000	2847.289	424.704	424.501	424.965	424.359	424.723
193312.000	193312.000	193312.000	193273.000	193312.002	127827.388	127798.160	127292.822	127494.320	127472.791
37084.000	37084.000	37084.000	37121.000	37084.000	25081.575	25134.846	25145.323	25069.527	25120.582
1.000					175.000				
0.000	0.000	803.989	0.000	267.996	223365.748	224843.369	225032.465	223814.885	224413.859
26.018	1.660	1.890	19.444	9.856	525.923	529.113	529.429	527.363	528.155
0.000	0.900	-0.033	0.000	-0.011	445.857	448.870	449.862	446.901	448.196
26.018	1.660	1.923	19.444	9.867	80.066	80.243	79.567	80.462	79.959
0.000	0.000	-0.017	0.000	-0.006	5.569	5.594	5.654	5.554	5.605
0.000	0.900	425.360	0.000	141.787	424.712	424.944	425.048	424.404	424.901
193311.592	193311.590	193253.328	193272.639	193292.170	116677.337	116049.521	116041.978	116312.653	116255.979
37080.922	37082.467	37042.351	37118.393	37068.713	23065.176	23110.263	23138.215	23043.957	23104.551
2.000					200.000				
90489.926	18241.727	18678.752	90718.480	42470.135	223712.951	225301.125	225340.904	223981.473	224618.324
198.309	727.664	5.077	199.028	142.017	525.444	530.419	530.268	527.440	528.709
145.285	172.100	1.857	145.761	106.414	445.288	450.263	450.563	447.425	448.705
53.024	50.564	3.221	53.267	35.603	80.156	80.155	79.703	80.415	80.005
2.740	3.404	0.576	2.736	2.240	5.555	5.617	5.653	5.564	5.609
456.307	81.929	367A.758	455.807	1405.663	424.808	424.761	424.959	424.336	424.843
193254.586	193247.902	193252.043	193215.357	193251.512	105538.273	104798.611	104802.281	105118.821	105046.389
37035.013	37051.265	37039.589	37073.251	37041.956	21048.703	21085.344	21131.154	21019.791	21088.400
3.000					225.000				
189752.497	148596.117	147171.469	189935.553	161840.094	223580.605	224934.830	224726.674	223633.762	224280.699
425.002	356.421	333.307	425.767	371.710	526.207	530.694	528.631	527.192	528.511
347.974	292.279	264.918	348.406	301.724	445.813	450.105	449.121	447.088	448.346
77.628	64.542	60.389	77.161	69.986	80.394	80.589	79.510	80.103	80.165
4.518	4.529	3.874	4.504	4.307	5.545	5.585	5.649	5.581	5.593
446.475	416.445	441.549	446.103	434.823	424.891	423.097	425.111	424.198	424.366
192993.248	192997.498	193104.945	192953.736	193031.898	94386.872	93546.199	93523.608	93932.216	93818.960
36970.978	36996.052	36988.696	37008.776	36985.242	19030.790	19060.395	19129.079	18998.185	19073.420
3.502					250.000				
189958.520	180464.929	179795.936	190139.646	183406.324	223279.420	225905.428	226068.146	223852.723	225084.330
440.402	404.438	422.048	441.171	422.296	525.465	530.959	532.121	527.705	529.549
367.340	328.092	337.942	362.753	342.792	445.354	450.468	452.278	447.527	449.366
78.067	76.346	84.106	78.418	79.504	80.212	80.491	79.843	80.179	80.182
4.442	4.297	4.018	4.676	4.319	5.552	5.598	5.665	5.582	5.604
411.330	446.207	424.009	430.989	434.516	424.837	425.467	424.843	424.200	425.049
192814.207	192868.283	192950.205	192774.424	192870.896	83247.844	82278.954	82264.383	82734.904	82597.060
36931.751	36959.169	36949.606	36969.284	36946.842	17015.117	17038.518	17132.373	16976.417	17062.003
10.000					275.000				
223563.061	222392.677	222237.211	223944.734	222730.965	223371.191	224532.410	224614.711	223682.061	224172.770
525.484	518.712	523.976	527.074	522.724	525.855	531.006	528.355	527.757	528.405
444.280	438.351	442.200	445.858	441.610	445.701	450.702	448.900	447.071	448.434
81.204	80.360	81.777	81.216	81.114	80.154	80.304	79.455	80.182	79.971
5.471	5.455	5.407	5.490	5.444	5.561	5.612	5.650	5.576	5.608
425.442	428.740	424.136	424.883	426.106	424.777	422.844	425.121	424.241	424.247
190174.480	190271.629	190348.551	190106.541	190264.887	72098.883	71003.922	70962.145	71544.406	71354.950
36413.300	36448.355	36426.298	36446.833	36429.318	15000.447	15015.118	15131.107	14954.133	15048.891
25.000					300.000				
223194.117	224220.016	223920.176	223791.922	223778.102	223292.471	224405.820	224614.570	223636.639	224104.285
524.757	530.519	527.319	526.872	527.532	525.722	531.352	527.894	527.246	528.323
443.846	450.270	446.835	445.897	446.984	445.659	450.996	449.104	447.197	448.586
80.910	80.250	80.484	80.975	80.548	80.064	80.356	78.790	80.050	79.737
5.486	5.611	5.552	5.507	5.569	5.566	5.612	5.709	5.586	5.626
425.329	427.643	424.639	424.755	424.203	424.734	422.930	425.497	424.160	424.185
183515.801	183567.170	183645.701	183411.537	183576.225	60946.040	59722.941	59703.441	60357.967	60124.106
35192.949	35238.412	35206.388	35220.136	35212.583	12987.653	12995.815	13136.172	12931.404	13039.880
50.000					325.000				
223459.021	225694.469	225691.975	223993.990	224968.152	222518.305	224139.184	224760.131	206778.244	223645.871
525.668	529.246	531.665	527.610	528.859	524.389	531.740	527.101	484.015	527.743
445.015	448.447	451.173	446.990	448.329	445.140	451.616	448.254	406.984	448.337
80.654	80.399	80.540	80.730	80.531	79.249	80.174	78.847	77.031	79.407
5.518	5.583	5.601	5.535	5.567	5.617	5.636	5.685	5.283	5.646
425.093	426.446	424.500	424.544	425.346	424.338	421.558	425.459	426.182	423.785
172399.922	172310.139	172389.965	172246.266	172366.674	49804.513	48439.008	48495.400	49350.864	48912.974
33164.198	33224.176	33189.967	33182.030	33192.773	10978.460	10976.764	11133.740	10915.383	11029.521
75.000					350.000				
223492.719	225893.338	226066.771	223967.150	225150.773	217119.363	220344.320	220662.648	189129.617	219375.441
525.946	530.481	532.366	527.681	529.364	510.729	516.650	517.810	440.848	515.063
445.296	449.471	452.109	447.119	449.092	432.169	437.411	439.834	386.289	436.471
80.550	80.410	80.257	80.562	80.472	78.561	79.239	77.977	74.559	78.592
5.528	5.581	5.633	5.550	5.581	5.501	5.520	5.641	4.913	5.554
425.015	425.628	424.645	424.437	425.163	425.116	426.487	426.146	429.013	425.916
161256.791	161056.738	161116.090	161060.154	161142.541	38719.594	37156.963	37266.939	39862.858	37714.499
31138.529	31204.821	31173.077	31150.173	31172.143	8968.670	8955.953	9135.522	8995.426	9020.048
100.000					375.000				
223015.756	224155.699	224399.473	223744.404	223856.973	188845.416	188251.318	188786.004	185810.988	188627.578
524.824	529.044	527.822	527.217	527.230	439.715	438.679	436.937	432.491	438.444
444.556	448.372	448.344	446.804	447.091	365.407	363.949	364.525	358.406	364.627
80.268	80.672	79.478	80.414	80.139	74.908	74.730	72.412	74.085	73.817
5.538	5.558	5.641	5.556	5.579	4.917	4.870	5.034	4.838	4.941
424.934	423.699	425.142	424.387	424.592	429.473	429.133	432.067	429.630	430.224
150117.195	149812.324	149835.607	149871.496	149920.041	28990.462	27795.669	27422.807	30787.449	27902.979
29116.528	29182.405	29161.372	29121.944	29153.435	7046.572	7012.004	7225.056	7101.410	7094.544

TABLE AP 5-2 (Sheet 2 of 2)
ENGINE PERFORMANCE PROGRAM (PA49)

400.000									
183036.018	183776.564	184202.256	183829.236	183671.609	4.766	4.768	4.894	4.766	4.009
425.185	426.730	425.558	427.509	425.824	430.750	429.671	433.233	430.230	431.218
351.926	357.657	353.507	353.718	357.663	11312.785	9567.401	9682.424	13091.646	10187.537
73.359	74.073	72.050	73.791	73.161	3318.387	3254.323	3501.660	3341.533	3384.790
4.796	4.761	4.906	4.794	4.621					
430.485	430.662	432.849	430.000	431.332					
20048.806	18374.452	19469.160	21895.945	18964.073	442.849				
5175.663	5128.317	5399.198	5218.629	5234.393	180097.932	182325.564	182987.600	180641.834	181003.697
					417.918	421.772	422.972	419.512	420.854
					344.919	348.145	350.310	346.211	347.791
425.000					72.899	73.677	72.662	73.301	73.063
181994.922	182617.553	183035.844	182559.141	182512.770	4.731	4.728	4.821	4.723	4.760
422.252	425.017	422.488	424.329	423.253	431.044	432.285	432.674	430.600	431.984
349.017	351.336	350.810	350.741	350.388	5102.631	3312.930	3430.920	6848.147	3951.493
73.235	73.681	71.678	73.588	72.865	1995.277	1919.020	2279.743	2004.288	2064.680

1. FLIGHT SIMULATED DATA (AC77)

Presented in this appendix is a detailed five-degrees-of-freedom trajectory simulation constrained to the observed trajectory and employing adjusted engine analysis propulsion histories. Adjustments were determined by a differential correction technique which correlated perturbations in thrust, weight flow, and pitch and yaw thrust vector misalignment with the resulting differences in slant range altitude, earth-fixed velocity, and earth-fixed velocity azimuth angle between the observed and simulated trajectories. A complete discussion of the trajectory simulation may be found in section 8.5, Flight Simulation Analysis.

Table AP 6-1 furnishes the detailed reconstructed trajectory from S-IVB ignition to guidance commanded cutoff. The ignition and cutoff weights are based on the composite best estimate ignition and cutoff weights as discussed in section 15. Table 6-2 presents the trajectory parameter definitions.

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TABLE AP 6-1 (Sheet 1 of 7)
FLIGHT SIMULATED DATA (AC77)

	TIME	WEIGHT	F SB T	ALTITUDE	RANGE
1		V SB I	A SB C	A SB L	RANGE ANGLE
2	V SB I	V SB F	R SB S	PZ	DF SB L
3	X SB E	X SB P (M)	X SB S	PTA	A+ SB L
4	Y SB E	Y SB P (M)	Y SB S	ZETA	E+ SB L
5	Z SB E	Z SB P (M)	Z SB S	D-EI	A SB LM
6	D-X SB E	D-X SB P (M)	D-X SB S	D-ETA	A SB YM
7	D-Y SB E	D-Y SB P (M)	D-Y SB S	D-ZETA	A SB ZM
8	D-Z SB E	D-Z SB P (M)	D-Z SB S	D-ZETA	A SB ZM
9	F SB E	F SB TE	F SB AX	M SB X	M SB AX
10	F SB Y	F SB TY	F SB AY	M SB Y	M SB AY
11	F SB Z	F SB TZ	F SB AZ	M SB Z	M SB AZ
12	THETA(M) OPP	DTHETA(M)OPP	CHORD FORCE	I SB EE	EPSI(THETA)
13	PSI(M) OPP	D-PSI(M)OPP	NORMAL FORCE	I SB YY	EPSI(PSI)
14	PHI(M) OPP	D-PHI(M)OPP	F AUX SB R	I SB ZZ	EPSI(PHI)
15	CHI SB P	D-CHI SB P	THETA(P)	P SB M	R SB CG
16	CHI SB Y	D-CHI SB Y	THETA(Y)	Q SB M	Y SB CG
17	CHI SB R	D-CHI SB R	THETA(R)	R SB M	Z SB CG
18	GAMMA SB 1	GAMMA SB 11	GAMMA(1)IPR.	DELTA(A)	D-DELTA(A)
19	GAMMA SB 2	GAMMA SB 21	GAMMA(2)IPR.	DELTA(B)	D-DELTA(B)
20	E SB SP	AVG E SB SP	WEIGHT FLOW	AVG D-M	AVG F SB L
21	Q	MACH NO.	PRESSURE	TEMPERATURE	R SB CP
22	RU	RHO	RHO PRIME	GI(RHO)	GI(PSI)
23	ALPHA*	ALPHA	BETA	V SB W	E SB W
24	T(1)	TAU(1)G)	PHI(T)	T(V)	D-T(V)
25	T(3)	TAU(3)G)	SNCP	Y(V)	D-Y(V)
26	D-T(CO)	DELTA-T(3)	SNCY	Z(V)	D-Z(V)
27	SAFT(I)				
28	R(PER)	V(PER)	ECCENTRICITY	PERIOD	BETA
29	R(APO)	V(APO)	INCLINATION	E/M	BETA(F)
30	T SB P	S SB F	V(F)	MU SB F	RHO PRT.(F)
31	GAMMA SB 1F	GAMMA SB 2F			

FIRST MOTION

1	144.3300	314005.000	0.000	193851.135	186790.174
2	7370.9416	6165.3785	21103827.40	20909976.50	0.5173
3	1900462.166	0.000	385795.555	0.000	271294.148
4	192991.965	0.000	190253.736	0.000	104.0315
5	-3222.665	0.000	-57054.446	0.000	45.3468
6	9274.3373	0.0000	6609.2030	0.0000	0.8397
7	3192.5698	0.0000	3118.7573	0.0000	-0.0283
8	-27.9060	0.0000	-426.7116	0.0000	0.0070
9	8247.474	0.000	-596.099	63.437	63.437
10	-278.177	0.000	-278.177	-3636.084	-3636.084
11	68.542	0.000	68.542	-13393.684	-13393.684
12	29.9100	-0.0000	-596.0975	109644.403	29.9990
13	0.4000	0.0000	286.4864	9361891.375	0.0000
14	-0.0000	0.0000	8843.5712	9360680.875	0.0000
15	-60.0010	0.0000	0.0000	0.0000	448.5117
16	0.0000	0.0000	0.0000	0.0000	-1.0335
17	0.0000	0.0000	0.0000	0.0000	-2.4819
18	31.7031	26.2696	26.3023	0.0000	0.0000
19	104.9762	101.9167	101.8398	0.0000	0.0000
20	210.0089	210.0089	-42.1105	-42.1105	8843.571
21	13.6429	5.9315	0.5540	449.5910	1028.504
22	79.9911	28.3948	28.2356	-31.4727	-0.0421
23	0.7696	-0.7473	-0.1841	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	108.6688				
28					
29					
30					
31					

1	147.6700	315874.941	23767.146	203725.553	204836.934
2	7282.3603	6119.2942	21113712.25	20909986.25	0.5613
3	2069461.758	0.000	406220.556	0.000	289703.063
4	207212.504	0.000	199742.669	0.000	104.0849
5	-3309.387	0.000	-58372.814	0.000	44.4044
6	9276.2167	0.0000	6611.3677	0.0000	3.2111
7	3099.4551	0.0000	3023.3297	0.0000	-0.0121
8	-26.0187	0.0000	-426.6169	0.0000	-0.0207
9	31525.927	23744.084	-399.545	47.419	17.961
10	-315.534	-260.354	-55.345	-6904.720	-3722.041
11	-203.509	-278.670	75.314	2669.225	-2641.822
12	29.6723	-0.1119	-399.5848	109022.496	0.3267
13	C.2816	-0.0443	93.4478	9359989.125	-0.7816
14	-0.0000	0.0000	8181.4287	9358757.375	0.0000
15	-60.0010	0.0000	0.0000	0.0006	448.6436
16	0.0000	0.0000	0.0000	-0.1119	-1.0347
17	0.0000	0.0000	0.0000	-0.0443	-2.4846
18	30.9923	25.6381	25.6709	-0.6724	0.1081
19	105.0151	101.9465	101.8717	0.6282	0.0876
20	275.8730	210.0089	-115.7254	-42.1105	8843.571
21	9.2430	5.9957	0.3671	433.4712	1028.504
22	79.9429	28.3834	28.2241	-31.5931	-0.0420
23	0.3696	-0.2191	-0.2979	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	109.2391				
28					
29					
30					
31					

1	150.0000	314994.941	191762.484	211776.559	210761.711
2	7245.8424	6116.4670	21121773.75	20909998.00	0.5981
3	2205587.256	0.000	423310.859	0.000	305013.699
4	210676.461	0.000	207457.426	0.000	104.1244
5	-3371.134	0.000	-59473.734	0.000	43.6733
6	9307.9688	0.0000	6643.4456	0.0000	19.7240
7	3039.0819	0.0000	2960.7318	0.0000	-0.0593
8	-24.8743	0.0000	-426.7968	0.0000	-0.0730
9	193104.547	191759.484	-290.753	58.413	-11.214
10	-580.175	-646.365	107.901	8964.631	-6307.057
11	-716.611	-842.767	129.389	8659.936	5234.484
12	29.8289	0.2416	-290.7530	104907.876	0.1701
13	-0.1268	-0.1740	168.4716	9357634.125	0.1268
14	0.0000	-0.0001	1635.8968	9356423.125	0.0000
15	-60.0010	0.0000	0.0000	0.0005	448.8771
16	0.0000	0.0000	0.0000	0.2416	-1.0375
17	0.0000	0.0000	0.0000	-0.1740	-2.4912
18	30.3908	25.1316	25.1645	-0.2518	0.1089
19	105.0485	101.9861	101.9131	0.2051	-0.2690
20	430.7342	436.8403	-448.9899	-441.8505	193000.318
21	8.7424	6.0884	0.2599	419.9735	1028.220
22	79.9025	28.3738	28.2148	-31.5690	-0.0420
23	0.9193	0.5850	-0.7019	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	109.6864				
28	117.2048	195583.1523	0.9353	32.1963	178.1217
29	3503.1837	6543.5600	30.4353	339145567.0	-177.1468
30	416.1788	262.9161	8154.8740	75.8109	27.1398
31	-35.2363	104.5316			

1	155.0000	312582.120	221940.973	227011.893	244556.059
2	7324.5129	6143.6735	21137078.50	20910017.25	0.6701
3	2413336.827	0.000	456739.730	0.000	334765.367
4	225567.111	0.000	221994.906	0.000	104.1921
5	-3687.739	0.000	-61404.881	0.000	42.1614
6	9394.9084	0.0000	6731.1475	0.0000	22.0275
7	2939.2577	0.0000	2856.2946	0.0000	-0.0332
8	-21.8243	0.0000	-426.5444	0.0000	-0.1362
9	221778.520	221935.094	-156.577	-124.738	-41.570
10	-30.737	-261.143	229.968	-3613.617	-3432.259
11	-1517.960	-1591.142	74.744	-659.246	11083.515
12	30.3187	-0.0651	-156.5766	108890.695	-0.3197
13	-0.1923	0.0532	241.7139	9350041.125	0.1923
14	-0.0000	-0.0000	0.0000	9348836.625	0.0000
15	-60.0010	0.0000	0.0000	-0.0292	449.6247
16	0.0000	0.0000	0.0000	-0.0653	-1.0454
17	0.0000	0.0000	0.0000	0.0532	-2.5101
18	29.2520	24.1968	24.2299	-0.4113	-0.0299
19	105.1228	102.0870	102.0127	0.0474	0.0455
20	425.3741	428.4699	-521.7409	-476.4895	204046.949
21	3.6479	6.3092	0.1310	394.7091	1027.515
22	79.8235	28.3550	28.1962	-31.5234	-0.0418
23	2.4722	2.3036	-0.7494	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	110.4948				
28	120.9267	192781.5527	0.9335	32.2540	178.1492
29	3504.1875	6630.7323	30.4540	346781853.5	-177.0423
30	419.7889	269.7705	8247.8434	75.8891	27.1041
31	-35.0587	104.4457			

1	156.2220	311942.457	223177.371	230667.297	251045.093
2	7336.5550	6152.9863	21140688.75	20910022.00	0.6879
3	2539045.509	0.000	464979.410	0.000	342042.434
4	229144.678	0.000	225470.383	0.000	104.2072
5	-3514.004	0.000	-62178.148	0.000	42.0586
6	9418.0408	0.0000	6754.5029	0.0000	23.0042
7	2916.0236	0.0000	2831.9060	0.0000	-0.0247
8	-21.1810	0.0000	-426.6018	0.0000	-0.1633
9	223036.604	223170.850	-134.246	-87.934	-40.153
10	-239.555	-456.502	216.547	-4044.166	-2911.131
11	-1583.356	-1643.444	59.905	4249.519	10433.267
12	30.2456	-0.0482	-134.2455	108896.153	-0.2477
13	-0.1461	0.0220	224.6788	9348092.750	0.1466
14	0.0000	-0.0000	0.0000	9346887.250	0.0000
15	-60.0010	0.0000	0.0000	-0.0001	449.8186
16	0.0000	0.0000	0.0000	-0.0492	-1.0474
17	0.0000	0.0000	0.0000	0.0220	-2.5149
18	28.9765	23.9725	24.0057	-0.4219	0.0039
19	105.1398	102.1054	102.0363	0.1172	0.0207
20	425.1134	427.9291	-524.9678	-484.6085	207262.193
21	3.1314	6.3654	0.1104	388.8210	1027.332
22	79.8041	28.3503	28.1915	-31.5125	-0.0418
23	2.6228	2.5280	-0.6998	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	110.6821				
28	121.4188	192048.6563	0.9330	32.2694	178.1549
29	3504.4493	6651.9178	30.4585	346881622.0	-177.0652
30	420.7403	271.5915	8272.4348	75.8568	27.0947
31	-35.0107	104.4747			

ULLAGE ROCKET CASE JETTISON

1	156.2220	311720.156	223177.371	230667.297	251045.093
2	7336.5550	6152.9863	21140688.75	20910022.00	0.6879
3	2539045.509	0.000	464979.410	0.000	342042.434
4	229144.678	0.000	225470.383	0.000	104.2072
5	-3514.004	0.000	-62178.148	0.000	42.0586
6	9418.0408	0.0000	6754.5029	0.0000	23.0206
7	2916.0236	0.0000	2831.9060	0.0000	-0.0247
8	-21.1810	0.0000	-426.6018	0.0000	-0.1634
9	223036.604	223170.850	-134.246	-87.934	-40.153
10	-239.555	-456.502	216.547	-4044.166	-2911.131
11	-1583.356	-1643.444	59.905	4249.519	10433.267
12	30.2456	-0.0482	-134.2455	108896.153	-0.2466
13	-0.1461	0.0220	224.6788	9348092.750	0.1461
14	0.0000	-0.0000	0.0000	9346887.250	0.0000
15	-60.0010	0.0000	0.0000	-0.0001	449.8186
16	0.0000	0.0000	0.0000	-0.0482	-1.0474
17	0.0000	0.0000	0.0000	0.0220	-2.5149
18	28.9765	23.9725	24.0057	-0.4219	0.0121
19	105.1398	102.1054	102.0363	0.1172	0.0113
20	425.1134	427.9291	-524.9678	-484.6085	207262.193
21	3.1314	6.3654	0.1104	388.8210	1027.332
22	79.8041	28.3503	28.1915	-31.5125	-0.0418
23	2.6228	2.5280	-0.6998	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	110.6821				
28	121.4188	192048.6563	0.9330	32.2694	178.1549
29	3504.4493	6651.9178	30.4585	346881622.0	-177.0652
30	420.7403	271.5915	8272.4348	75.8568	27.0947
31	-35.0107	104.4747			

1	160.0000	309733.270	223715.203	241805.426	271276.599
2	7375.3190	6183.5769	21151841.25	20910036.75	0.7433
3	2745549.301	0.000	490635.258	0.000	366694.977
4	240026.711	0.000	236027.322	0.000	104.2307
5	-3590.306	0.000	-63740.230	0.000	41.1593
6	5490.4036	0.0000	6827.3611	0.0000	23.2296
7	2844.5956	0.0000	2756.8565	0.0000	-0.0182
8	-19.1843	0.0000	-426.7963	0.0000	-0.1547
9	223027.004	223209.713	-22.707	-93.950	-34.875
10	-174.941	-355.419	180.535	839.464	-1778.818
11	-1489.274	-1525.936	36.669	-594.862	8674.264
12	30.2117	0.0068	-82.7073	108008.817	-0.2127
13	-0.1501	-0.0033	184.2241	9338187.000	0.1501
14	-0.0000	0.0000	0.0000	9336985.250	0.0000
15	-60.0010	0.0000	0.0000	0.0000	450.6657
16	0.0000	0.0000	0.0000	0.0068	-1.0544
17	0.0000	0.0000	0.0000	-0.0033	-2.5324
18	28.1316	23.2853	23.3187	-0.3908	-0.0013
19	105.1923	102.1775	102.1107	0.0910	-0.0238
20	425.0672	426.9579	-526.2926	-488.9575	212932.031
21	1.9365	6.5453	0.0646	371.4145	1026.755
22	79.7633	28.3357	28.1771	-31.4791	-0.0417
23	3.4775	3.4080	-0.6934	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	111.2386				
28	124.2274	189792.5352	0.9315	32.3177	178.1722
29	3505.2548	6726.3106	30.4724	355171867.0	-177.0117
30	423.6916	277.2758	8348.8763	75.9557	27.0652
31	-34.8588	104.5644			

TABLE AP 6-1 (Sheet 2 of 7)
FLIGHT SIMULATED DATA (AC77)

1	165.0000	307094.258	223918.148	296169.740	298441.233
2	7479.6293	6227.5757	21166225.50	20910056.75	0.8178
3	922742.195	0.000	229814.586	0.000	396825.191
4	254514.652	0.000	249564.822	0.000	104.3025
5	-3679.533	0.000	-65874.795	0.000	40.0427
6	5547.0208	0.0000	6924.6178	0.0000	23.4167
7	2730.9319	0.0000	2658.3125	0.0000	-0.0372
8	-16.5295	0.0000	-427.0487	0.0000	-0.1662
9	223669.648	223931.449	-42.739	-64.998	-25.188
10	-154.889	-480.906	125.948	-226.373	-860.949
11	-1575.946	-16064.185	18.214	277.237	6032.4525
12	30.1693	-0.0045	-42.7351	107998.937	-0.1903
13	-0.1140	0.0029	127.2584	9329481.750	0.1340
14	0.0000	-0.0000	0.0000	9327764.625	0.0000
15	-60.0010	0.0000	0.0000	-0.0000	451.5717
16	0.0000	0.0000	0.0000	-0.0083	-1.0633
17	0.0000	0.0000	0.0000	0.0029	-2.5536
18	27.0318	22.3927	22.4263	-0.4104	-0.0011
19	105.2618	102.2727	107.2049	0.1210	0.0036
20	423.9994	426.2553	-529.1420	-508.0404	216671.406
21	1.0054	6.7916	0.0312	349.2830	1029.944
22	79.6618	28.3161	28.1577	-31.4366	-0.0416
23	6.4249	6.5775	-0.6634	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	111.9241				
28	128.0179	186849.9141	0.9295	32.3827	178.1956
29	3506.3024	6823.0961	30.4906	363721139.0	-176.9401
30	427.6099	286.8885	8450.4109	75.4205	27.0257
31	-34.6528	104.6830			

1	168.9300	305015.402	223918.051	267162.879	320108.129
2	7474.5850	6264.8149	21177234.25	20910072.75	0.8771
3	924349.352	0.000	552379.422	0.000	418655.762
4	264681.945	0.000	259860.557	0.000	104.3393
5	-3740.431	0.000	-67553.578	0.000	39.2139
6	5663.6334	0.0000	7001.6764	0.0000	23.6162
7	2677.8659	0.0000	2581.3584	0.0000	-0.0477
8	-14.4472	0.0000	-427.2835	0.0000	-0.1691
9	223886.463	223911.576	-25.112	-47.307	-18.121
10	-447.556	-536.557	88.964	21.619	-505.450
11	-1605.231	-1615.714	10.472	29.616	4250.375
12	30.1669	-0.0044	-25.1121	107991.170	-0.1680
13	-0.1280	0.0012	89.5786	9321710.625	0.1280
14	0.0000	-0.0000	0.0000	9320517.250	0.0000
15	-60.0010	0.0000	0.0000	-0.0000	452.2838
16	0.0000	0.0000	0.0000	-0.0044	-1.0703
17	0.0000	0.0000	0.0000	0.0012	-2.5703
18	26.1821	21.7041	21.7378	-0.4134	-0.0011
19	105.3159	102.3471	102.2855	0.1373	0.0034
20	424.0064	425.4913	-528.0856	-512.1806	218060.318
21	0.5937	7.0000	0.0173	333.3174	1025.296
22	79.5968	28.3004	28.1421	-31.4039	-0.0415
23	5.5157	5.4781	-0.6468	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	112.4371				
28	131.1076	184572.4570	0.9279	32.4346	178.2143
29	3507.1241	6899.9108	30.5047	370528?4.5	-176.8832
30	430.6908	290.9341	8530.4885	75.3133	26.9941
31	-34.4868	104.7757			

LAUNCH ESCAPE TOWER JETTISON

1	168.9300	296404.602	223918.051	267162.879	320108.129
2	7474.5850	6264.8149	21177234.25	20910072.75	0.8771
3	924349.352	0.000	552379.422	0.000	418655.762
4	264681.945	0.000	259860.557	0.000	104.3393
5	-3740.431	0.000	-67553.578	0.000	39.2139
6	5663.6334	0.0000	7001.6764	0.0000	24.3023
7	2677.8659	0.0000	2581.3584	0.0000	-0.0486
8	-14.4472	0.0000	-427.2835	0.0000	-0.1742
9	223886.463	223911.576	-25.112	-47.307	-18.121
10	-447.556	-536.557	88.964	21.619	-505.450
11	-1605.231	-1615.714	10.472	29.616	4250.375
12	30.1669	-0.0044	-25.1121	107991.170	-0.1679
13	-0.1280	0.0012	89.5786	9321710.625	0.1280
14	0.0000	-0.0000	0.0000	9320517.250	0.0000
15	-60.0010	0.0000	0.0000	-0.0000	452.2838
16	0.0000	0.0000	0.0000	-0.0044	-1.0703
17	0.0000	0.0000	0.0000	0.0012	-2.5703
18	26.1821	21.7041	21.7378	-0.4134	-0.0011
19	105.3159	102.3471	102.2855	0.1373	0.0034
20	424.0064	425.4913	-528.0856	-512.1806	218060.318
21	0.5937	7.0000	0.0173	333.3174	1025.296
22	79.5968	28.3004	28.1421	-31.4039	-0.0415
23	5.5157	5.4781	-0.6468	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	112.4371				
28	131.1076	184572.4570	0.9279	32.4346	178.2143
29	3507.1241	6899.9108	30.5047	37052874.5	-176.8832
30	430.6908	290.9341	8530.4885	75.3133	26.9941
31	-34.4868	104.7757			

1	170.0000	295838.570	223947.377	270110.813	326056.074
2	7487.8829	6276.0584	21180187.25	20910077.00	0.8934
3	930470.951	0.000	559482.749	0.000	425168.000
4	267536.867	0.000	262011.594	0.000	104.3488
5	-3755.566	0.000	-68010.756	0.000	38.9947
6	5685.2032	0.0000	7023.3630	0.0000	24.3522
7	2658.4171	0.0000	2560.8111	0.0000	-0.0566
8	-13.8885	0.0000	-427.3642	0.0000	-0.1927
9	223917.783	223939.486	-21.703	-47.712	-16.940
10	-520.049	-600.484	80.326	1277.358	-443.144
11	-1772.304	-1781.273	8.717	-407.742	4041.495
12	30.1560	-0.0141	-21.7030	107419.512	-0.1570
13	-0.1063	0.0329	80.7978	7147630.875	0.1063
14	-0.0000	-0.0000	0.0000	7146449.500	0.0000
15	-60.0010	0.0000	0.0000	-0.0000	421.6335
16	0.0000	0.0000	0.0000	-0.0141	-1.1007
17	0.0000	0.0000	0.0000	0.0329	-2.6507
18	25.9537	21.5195	21.5534	-0.4557	-0.0033
19	105.3306	102.3675	102.3065	0.1596	0.0166
20	423.8201	425.8049	-529.3833	-513.0418	218385.160
21	0.5137	7.0615	0.0147	328.7100	1025.098
22	79.5790	28.2961	28.1378	-31.3952	-0.0414
23	5.7490	5.7157	-0.6223	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	112.5712				
28	131.9785	183940.6230	0.9275	32.4493	178.2190
29	3507.3505	6921.5242	30.5086	37244880.5	-176.8672
30	431.5535	292.6363	8552.9346	75.2830	26.9853
31	-34.4397	104.8015			

1	175.0000	293168.000	224874.594	285549.941	334210.237
2	7551.3739	6329.9993	21193646.75	20910094.00	0.9175
3	359173.359	0.000	595326.094	0.000	455347.566
4	240510.137	0.000	275083.148	0.000	104.3465
5	-3845.424	0.000	-70175.766	0.000	37.9578
6	5787.7953	0.0000	7126.2965	0.0000	24.6783
7	2543.4198	0.0000	2460.6780	0.0000	0.0353
8	-12.6190	0.0000	-429.0994	0.0000	0.0307
9	224866.396	224874.469	-10.497	-10.299	-10.299
10	48.701	0.000	48.701	49817.290	-353.673
11	6.002	0.000	6.002	-18372.978	2465.677
12	30.4000	-0.0000	-10.4979	107409.097	31.6511
13	-0.3700	0.0000	49.0599	7142735.844	-0.4239
14	-0.0000	0.0000	0.0000	7141559.438	0.0000
15	-58.3999	0.0000	0.0000	0.0000	427.4595
16	-0.4239	0.0000	0.0000	0.0000	-1.1109
17	0.0000	0.0000	0.0000	0.0000	-2.6746
18	24.8569	20.6336	20.6676	0.0000	0.0000
19	105.3855	102.4522	102.3941	0.0000	0.0000
20	424.4384	424.4384	-529.8175	-529.8175	224874.891
21	0.2492	7.1609	0.0000	325.1700	1024.779
22	79.4946	28.2758	28.1175	-31.3551	-0.0413
23	7.2035	7.1499	-0.8454	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	113.1765				
28	136.1665	180986.5879	0.9255	32.5182	178.2441
29	3508.3130	7024.5945	30.5227	38144533.0	-176.7939
30	435.3228	303.4742	8657.3536	75.1437	26.9653
31	-34.1949	104.9096			

1	180.0000	290518.094	224909.477	296661.438	302766.652
2	7617.1274	6347.6104	21206779.50	20910119.25	1.0448
3	388363.195	0.000	611210.102	0.000	486575.816
4	293109.586	0.000	297196.023	0.000	104.4747
5	-3899.285	0.000	-72319.531	0.000	37.0415
6	5887.1104	0.0000	7224.1486	0.0000	24.9379
7	2478.5958	0.0000	2370.6755	0.0000	-0.1391
8	-7.8395	0.0000	-427.3646	0.0000	-0.1029
9	224900.111	224909.203	-5.092	135.219	-8.971
10	-985.094	-1021.467	43.216	24932.317	-402.994
11	-929.295	-937.141	8.019	8855.459	2166.229
12	35.2408	0.8446	-5.0915	107398.591	1.2329
13	-1.9744	-0.0171	43.9537	7137840.500	0.2457
14	0.0000	-0.0000	0.0000	7136669.375	0.0000
15	-55.5269	0.0000	0.0000	0.0000	421.2774
16	-1.7311	0.0000	0.0000	0.0841	-1.1212
17	0.0000	0.0000	0.0000	-0.0171	-2.6995
18	23.8802	19.8653	19.8799	-0.2397	-0.1864
19	105.6749	102.5629	102.5072	0.2672	0.0169
20	424.5019	424.4441	-529.7098	-529.9708	224948.506
21	0.1209	7.2508	0.0031	327.4520	1024.691
22	79.4091	28.2547	28.0968	-31.3161	-0.0412
23	13.2913	13.0760	-2.4677	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	113.7430				
28	140.2938	178276.7812	0.9231	32.5882	178.2666
29	3509.4106	7123.9959	30.5463	39034595.0	-176.7171
30	439.6049	308.6742	8781.6548	74.9989	26.9004
31	-33.9926	105.0460			

1	190.0000	295270.156	224439.373	321875.672	441202.891
2	7744.4850	6505.8073	21232037.25	20910161.00	1.2089
3	448170.254	0.000	704413.313	0.000	549350.164
4	317150.977	0.000	330066.117	0.000	104.4995
5	-3914.588	0.000	-76560.813	0.000	35.2464
6	6073.4695	0.0000	7413.5986	0.0000	25.3184
7	2332.9940	0.0000	2213.4432	0.0000	-0.1099
8	-4.6113	0.0000	-421.0449	0.0000	-0.2147
9	224427.875	224429.139	-1.263	42.708	-5.733
10	-974.250	-990.249	14.806	-155.766	-83.204
11	-1899.008	-1900.724	1.697	6170.951	741.248
12	38.4684	-0.1988	-1.2633	107377.490	-0.2588
13	-1.6933	0.0076	14.8985	7124050.063	0.0679
14	0.0000	-0.0004	0.0000	7126899.250	0.0000
15	-51.7906	0.0000	0.0000	-0.0047	424.9224
16	-1.6463	0.0000	0.0000	-0.1587	-1.1414
17	0.0000	0.0000	0.0000	0.0176	-2.7479
18	22.2136	18.5975	18.5423	-0.4452	-0.0019
19	105.6779	102.7976	102.7461	0.2528	-0.0046
20	424.3363	424.5825	-528.8945	-529.8678	224964.281
21	0.0298	6.9093	0.0009	364.9527	1025.587
22	79.2362	28.2115	28.0540	-31.2421	-0.0409
23	18.2712	18.1654	-2.1024	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	114.7922				
28	148.2238	173186.8406	0.9197	32.7272	178.2975
29	3511.8527	7309.6428	30.5942	40853362.5	-176.5629
30	449.2308	325.7011	8984.2742	74.6991	26.8059
31	-33.6889	105.3358			

1	200.0000	279918.469	225540.609	349856.824	503382.113
2	7990.4219	6695.9179	21254064.25	20910208.75	1.3738
3	509856.273	0.000	779504.773	0.000	612696.078
4	339748.367	0.000	331429.527	0.000	104.5723
5	-3806.635	0.000	-80741.156	0.000	33.6772
6	6765.1115	0.0000	7806.0201	0.0000	25.9228
7	2187.1799	0.0000	2037.9098	0.0000	-0.0956
8	17.1837	0.0000	-414.8444	0.0000	-0.2249
9	225553.172	225550.531	-0.345	4.622	-0.999
10	-831.534	-837.307	4.446	-733.145	-25.419
11	-1956.920	-1957.165	0.506	1133.505	222.928
12	36.8228	-0.1642	-0.3803	107356.479	-0.3151
13	-1.8369	-0.0334	4.4951	7118259.625	-0.0249
14	0.0000	-0.0000	0.0000	7117109.125	0.0000
15	-53.4925	0.0000	0.0000	-0.0594	426.5669
16	-1.8609	0.0000	0.0000	-0.1681	-1.1621
17	0.0000	0.0000	0.0000	-0.0334	-2.7967
18	20.6171	17.2258	17.2612	-0.4972	0.0015
19	105.6970	103.0297	102.9821	0.2127	-0.0301
20	424.8877	424.7071	-530.4004	-529.9734	225363.670
21	0.0089	6.5639	0.0003	427.9264	1026.759
22	79.0544	28.1665	28.0093	-31.1716	-0.0407
23	18.4272	18.3172	-2.1546	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	115.7449				
28	156.6489	168273.8984	0.9147	32.8719	178.3319
29	3514.2106	7500.9409	30.6491	42712643.0	-176.4049
30	458.8260	343.2044	9186.9982	74.3929	26.7076
31	-33.3498	109.6738			

TABLE AP 6-1 (Sheet 3 of 7)
FLIGHT SIMULATED DATA (AC77)

1	210.0000	274606.883	274460.907	364608.875	563305.328	1	250.0000	253406.041	225037.935	447592.652	631362.375
2	8044.0930	6779.9509	21278884.00	20910754.25	1.5437	2	8765.6979	7484.5926	21158058.50	20910467.50	2.2772
3	573494.055	0.000	836558.516	0.000	677608.125	3	848951.438	0.000	1105668.359	0.000	959971.672
4	360884.551	0.000	351214.777	0.000	134.8438	4	430732.720	0.000	414442.781	0.000	134.9218
5	-3563.264	0.000	-44852.647	0.000	32.1807	5	-1155.128	0.000	-103535.012	0.000	26.9314
6	6444.4017	0.0000	7805.4171	0.0000	26.2975	6	7325.8129	0.0000	8666.4419	0.0000	28.5707
7	2040.7622	0.0000	1903.1438	0.0000	-0.0981	7	1450.6453	0.0000	1260.0354	0.0000	-0.1187
8	31.2428	0.0000	-407.2751	0.0000	-0.2212	8	89.2798	0.0000	-377.1865	0.0000	-0.2659
9	224451.006	224451.145	-0.137	11.169	-0.369	9	225026.033	225026.000	-0.924	19.018	-0.071
10	-837.673	-840.323	1.431	1159.446	-0.444	10	-934.782	-935.350	0.004	-526.257	-0.250
11	-1905.016	-1905.209	0.148	894.059	51.452	11	-2071.128	-2071.082	0.006	2795.126	3.255
12	35.4711	-0.1295	-0.1372	107355.272	-0.2452	12	31.1435	-0.0599	-0.0245	107230.195	-0.1304
13	-2.0260	0.0176	1.6415	7097717.750	0.0489	13	-1.7817	-0.0044	0.0843	7015521.255	-0.0197
14	-0.0000	-0.0000	0.0000	7996500.125	0.0307	14	0.0000	-0.0001	0.0000	7014637.000	0.0001
15	-54.7739	0.0000	0.0003	-0.0046	420.8633	15	-58.9872	0.0000	0.0000	-0.0019	437.0917
16	-1.9771	0.0000	0.0000	-0.1396	-1.1862	16	-1.8014	0.0000	0.0000	-0.0597	-1.2818
17	0.0000	0.0000	0.0000	0.0104	-2.8538	17	0.0000	0.0000	0.0000	-0.0044	-3.0824
18	19.0278	15.9763	16.0122	-0.4464	-0.0324	18	19.4753	11.4518	11.4903	-0.5273	0.0116
19	106.0447	103.2363	103.2264	-0.2145	0.0398	19	106.8906	104.2105	104.1799	0.2381	-0.0188
20	423.4779	424.4546	-529.5195	-532.1396	225199.613	20	424.9233	424.6653	-529.5811	-532.1519	225147.973
21	0.0032	6.1144	0.0001	511.5100	1028.137	21	0.0003	4.3256	0.0009	1240.5249	932.111
22	78.6693	29.1196	27.9627	-31.1049	-0.0405	22	78.0736	27.9105	27.7549	-30.4249	-0.0397
23	18.6422	18.7264	-2.7636	0.0003	0.0003	23	20.9068	20.8536	-1.6320	0.0003	0.0003
24	0.0000	0.0000	0.0000	0.003	0.0003	24	0.0000	0.0000	0.0000	0.003	0.0003
25	0.0000	0.0000	0.0003	0.003	0.0003	25	0.0000	0.0000	0.0003	0.003	0.0003
26	0.0000	0.0000	0.0003	0.003	0.0003	26	0.0000	0.0000	0.0003	0.003	0.0003
27	116.4196					27	119.5725				
28	165.7019	163411.5176	0.9105	33.0236	178.3669	28	208.4074	144883.2363	0.8883	33.7557	178.5329
29	3516.4426	7705.3796	30.7033	44646552.5	-176.2427	29	3524.2691	8547.6595	30.9090	53164468.0	-175.5496
30	466.2467	341.1561	9377.1969	74.0778	26.6059	30	501.0245	437.7103	10243.9999	72.7444	26.1589
31	-32.9824	105.9197				31	-31.0831	107.0815			
1	220.0000	269310.082	225026.502	390139.566	627285.289	1	260.0000	248107.225	225432.207	464432.672	903250.039
2	8208.2414	6933.5483	21300444.99	20910304.00	1.7185	2	8972.6483	7689.9199	21374957.25	20910526.00	2.4753
3	639163.719	0.000	935639.773	0.000	763885.234	3	923362.586	0.000	1273681.797	0.000	1024782.938
4	380559.363	0.000	369423.090	0.000	104.7149	4	444502.344	0.000	426257.961	0.000	104.9801
5	-3180.860	0.000	-88886.805	0.000	30.7693	5	-191.312	0.000	-104270.176	0.000	25.7059
6	6669.8972	0.0000	8011.5321	0.0000	26.8822	6	7557.6732	0.0000	8897.3672	0.0000	29.2327
7	1893.2731	0.0000	1740.8957	0.0000	-0.1047	7	1303.5223	0.0000	1099.1497	0.0000	-0.1094
8	45.6198	0.0000	-399.6744	0.0000	-0.2386	8	104.0436	0.0000	-369.8896	0.0000	-0.2695
9	225015.661	225015.926	-0.043	11.187	-0.164	9	225421.025	225421.045	-0.014	-5.298	-0.014
10	-876.266	-877.734	0.707	-524.576	-3.659	10	-843.262	-844.718	0.044	144.017	-0.162
11	-1996.991	-1997.144	0.073	1345.675	35.221	11	-2078.059	-2078.152	0.004	-655.035	2.187
12	34.2412	-0.0958	-0.0626	107314.053	-0.1937	12	30.3990	-0.1090	-0.0183	107226.585	-0.2163
13	-1.9652	0.0131	0.7112	7077169.125	0.0188	13	-1.7212	0.0128	0.0638	6985971.313	-0.0214
14	0.0000	-0.0001	0.0000	7078044.313	0.0003	14	-0.0000	0.0001	0.0000	6984899.688	0.0001
15	-55.9526	0.0000	0.0000	-0.0033	431.1206	15	-59.4171	0.0000	0.0000	-0.0033	441.1655
16	-1.9262	0.0000	0.0000	-0.0959	-1.2100	16	-1.7229	0.0000	0.0000	-0.1009	-1.3119
17	0.0000	0.0000	0.0003	0.0101	-2.9113	17	0.0000	0.0000	0.0000	0.0108	-3.1533
18	17.5640	14.7441	14.8046	-0.5085	-0.0116	18	12.2581	10.4565	10.4952	-0.5282	-0.0092
19	106.2896	103.5094	103.4692	0.2231	-0.0089	19	107.0713	104.4396	104.4114	0.2144	0.0104
20	424.4259	424.4595	-530.1643	-530.1674	225140.791	20	424.5948	424.6953	-530.9211	-530.1744	225164.537
21	0.0014	5.6367	0.0001	629.4362	1028.504	21	0.0002	4.1443	0.0000	1425.3075	890.916
22	78.6749	28.0705	27.9140	-31.0419	-0.0403	22	77.8598	27.8525	27.6973	-30.4262	-0.0395
23	19.2985	19.2035	-2.0642	0.0003	0.0003	23	21.6001	21.4577	-1.4889	0.0000	0.0003
24	0.0000	0.0000	0.0000	0.000	0.0003	24	0.0000	0.0000	0.0000	0.000	0.0003
25	0.0000	0.0000	0.0003	0.000	0.0003	25	0.0000	0.0000	0.0003	0.003	0.0003
26	0.0000	0.0000	0.0003	0.003	0.0003	26	0.0000	0.0000	0.0000	0.000	0.0003
27	117.4301					27	120.2126				
28	175.3577	156645.1680	0.9051	33.1820	178.4053	28	220.9220	140486.5000	0.8821	33.8996	178.5776
29	3516.4512	7906.5621	30.7567	44659688.5	-176.0765	29	3525.9809	8802.2494	30.9570	55520999.0	-175.3434
30	477.5294	379.5253	9588.1893	73.7969	26.6991	30	514.1441	458.2607	10471.1492	72.3887	26.0365
31	-32.5377	106.2137				31	-30.5489	107.3671			
1	230.0000	244002.793	225370.512	410664.422	693151.688	1	270.0000	242792.482	225184.215	482168.172	977690.297
2	8383.4718	7159.3389	21320421.00	20910357.75	1.8999	2	9190.4451	9882.8522	21390753.50	20910586.75	2.6799
3	704914.117	0.000	1016810.602	0.000	811631.633	3	1000127.344	0.000	1363638.578	0.000	1099509.938
4	398756.102	0.000	386035.137	0.000	104.7852	4	456801.301	0.000	436442.121	0.000	105.0529
5	-2652.394	0.000	-92844.944	0.000	29.4261	5	923.246	0.000	-107933.837	0.000	24.3482
6	6881.9860	0.0000	8221.5712	0.0000	27.4585	6	7796.7366	0.0000	9135.3069	0.0000	29.9190
7	1746.2734	0.0000	1581.6446	0.0000	-0.1003	7	1155.9134	0.0000	937.2781	0.0000	-0.1343
8	60.1037	0.0000	-392.0009	0.0000	-0.2434	8	118.8389	0.0000	-362.4778	0.0000	-0.2775
9	225309.594	225309.669	-0.058	-1.908	-0.017	9	225172.115	225172.131	-0.016	41.821	-0.011
10	-823.397	-824.634	0.391	277.778	-1.351	10	-1026.073	-1026.979	0.050	579.690	-0.112
11	-1997.591	-1997.620	0.028	-268.349	14.334	11	-2094.613	-2094.664	0.003	4787.659	1.827
12	33.4049	-0.1177	-0.0535	107292.883	-0.2210	12	29.0620	-0.1097	-0.0145	107202.774	-0.1499
13	-1.9207	0.0000	0.3028	7059620.500	0.0095	13	-1.6559	0.0058	0.0503	6956413.938	-0.0187
14	-0.0000	0.0001	0.0000	7059508.563	0.0007	14	0.0000	-0.0002	0.0000	6955357.000	0.0001
15	-56.8721	0.0000	0.0000	-0.0039	433.3976	15	-61.0478	0.0000	0.0000	-0.0032	444.3797
16	-1.9112	0.0000	0.0000	-0.1176	-1.2339	16	-1.6746	0.0000	0.0000	-0.1097	-1.3409
17	0.0000	0.0000	0.0003	0.0000	-2.9681	17	0.0000	0.0000	0.0000	0.0058	-3.2239
18	16.1554	13.6138	13.6507	-0.5043	0.0024	18	11.1088	9.5124	9.5515	-0.5329	-0.0087
19	106.4904	103.7459	103.7091	0.2097	0.0293	19	107.2581	104.6857	104.6606	0.2113	0.0357
20	424.4197	424.6511	-530.6152	-530.2680	225179.109	20	424.3784	424.6678	-530.5929	-530.2616	225185.265
21	0.0007	5.0181	0.0000	833.1235	1003.727	21	0.0001	4.0727	0.0000	1597.9704	883.407
22	78.4890	28.0194	27.8632	-30.8827	-0.0401	22	77.6397	27.7920	27.6372	-30.7808	-0.0396
23	20.0903	20.0103	-1.9458	0.0000	0.0000	23	21.6422	21.6075	-1.3501	0.0003	0.0003
24	0.0000	0.0000	0.0000	0.000	0.0003	24	0.0000	0.0000	0.0000	0.003	0.0003
25	0.0000	0.0000	0.0003	0.003	0.0003	25	0.0000	0.0000	0.0000	0.003	0.0003
26	0.0000	0.0000	0.0003	0.000	0.0003	26	0.0000	0.0000	0.0000	0.000	0.0003
27	118.1872					27	120.6240				
28	185.6677	153964.9844	0.8998	33.3402	178.4453	28	234.3024	136175.1426	0.8754	34.1023	178.6252
29	3520.6629	8119.6161	30.8049	46939968.5	-175.9057	29	3527.5937	9044.7396	31.0033	57985249.5	-175.1716
30	486.7688	398.4251	9802.9075	73.4274	26.3893	30	523.2412	479.4008	10703.5316	72.0233	25.9101
31	-32.0816	106.5057				31	-29.9916	107.6503			
1	240.0000	258699.764	274906.888	429612.621	761053.289	1	280.0000	237492.207	225126.412	496814.594	1054463.500
2	8549.1367	7278.7711	21340021.75	20910411.50	2.0854	2	9418.5625	8106.7822	21405463.25	20910690.00	2.8891
3	776825.133	0.000	1100132.750	0.000	880950.492	3	1079319.547	0.000	1456209.578	0.000	1176265.094
4	415484.391	0.000	401031.887	0.000	104.8541	4	467616.402	0.000	444996.461	0.000	105.1167
5	-1978.082	0.000	-96724.871	0.000	28.1403	5	2185.640	0.000	-111524.031	0.000	23.4247
6	7100.5618	0.0000	8461.8194	0.0000	27.9773	6	8042.8800	0.0000	9379.9727	0.0000	30.4971
7	1599.0369	0.0000	1421.6705	0.0000	-0.1105	7	1007.0384	0.0000	773.4411	0.0000	-0.1278
8	74.7231	0.0000	-384.4599	0.0000	-0.2567	8	133.6979	0.0000	-355.9910	0.0000	-0.2910
9	224955.744	224955.803	-0.036	9.580	-0.032	9	225114.164	225114.182	-0.012	13.878	-0.011
10	-888.548	-889.668	0.133	-580.982	-0.466	10	-943.435	-944.076	0.042	-424.872	-0.095
11	-2044.171	-2044.254	0.011	1284.441	5.485	11	-2147.958	-2148.018	0.002	1621.931	1.525
12	32.0430	-0.1239	-0.0356	107271.613	-0.2259	12	28.1922	-0.0729	-0.0120	107178.984	-0.1299
13	-1.8206	0.0089	0.1334	7036071.875	0.0057	13	-1.5958	0.0070	0.0422	6926856.625	-0.0122
14	-0.0000	-0.0001	0.0000	7034972.750	0.0003	14	0.0000	-0.0001	0.0000	6925814.250	0.0001
15	-58.1421	0.0000	0.0000	-0.0039	435.6767	15	-61.9376	0.0000	0.0000	-0.0020	447.5960
16	-1.8156	0.0000	0.0003	-0.1229	-1.2578	16	-1.6371	0.0000	0.0000	-0.0720	-1.3704
17	0.0000	0.0000	0.0000	0.0089	-3.0253	17	0.0000	0.0000	0.0003	0.0070	-3.2943
18	14.7743	12.5098	12.5474	-0.5217	0.0024	18	10.0228	8.6153	8.6550	-0.5467	-0.0083
19	106.6880	103.9800	103.9464	0.2266	0.0006	19	107.4424	104.8899	104.8672	0.2403	0.0224
20	424.8980	424.6748	-529.4349	-530.2726	225193.641	20	424.8160	424.6271	-529.9098	-530.2388	225156.049
21	0.0004	4.5971	0.0003	1043.2353	930.335	21	0.0001	3.9517	0.0000	1751.1047	881.636
22	78.2813	27.9661	27.8102	-30.9271	-0.0399	22	77.4131	27.7291	27.5745	-30.7385	-0.0392
23	20.1525	20.2685	-1.7554	0.0003	0.0003	23	22.0458	22.0679	-1.2285	0.0003	0.0003
24	0.0000	0.0000	0.0000	0.000	0.0003	24	0.0000	0.0000	0.0000	0.000	0.0003
25	0.0000	0.0000	0.0000	0.000	0.0003	25	0.0000	0.0000	0.0000	0.003	0.0003
26	0.0000	0.0000	0.0000	0.003	0.0003	26	0.0000	0.0000	0.0000	0.003	0.0003
27	118.6991					27	121.4101				
28	196.6669	149378.2070	0.8942	33.5226	178.4872	28	248.5849	131955.7598	0.8684	34.3173	178.6758
29	3522.4729	8340.0942	30.8599	90905447.5	-175.7300	29	3529.1013	9296.9276	31.0440	60599989.0	-174.9739
30	495.9436	417.8337	10021.4189	73.0898	26.2757	30	532.2857	501.1102	10941.0868	71.6488	25.7793
31	-31.5965	106.7954				31	-29.4133	107.9316			

TABLE AP 6-1 (Sheet 4 of 7)
FLIGHT SIMULATED DATA (AC77)

1	290.0000	232195.941	225381.408	508400.145	1133642.578	1	330.0000	211011.498	224231.721	552065.453	1476261.094
2	9656.4382	8341.3335	21419114.00	20910716.00	3.1063	2	10715.7216	9391.2852	21463870.00	20911096.93	4.0449
3	1161005.688	0.000	1551258.391	0.000	1255158.531	3	1514265.906	0.000	1957691.953	0.000	1594402.813
4	476545.090	0.000	451912.906	0.000	105.1775	4	499440.242	0.000	463121.094	0.000	105.4575
5	3597.544	0.000	-115054.625	0.000	22.3329	5	10769.714	0.000	-120498.001	0.000	18.2545
6	8295.6534	0.0000	9631.0005	0.0000	31.2201	6	9385.1967	0.0000	10710.6750	0.0000	34.1877
7	856.9857	0.0000	609.9848	0.0000	-0.1247	7	264.9458	0.0000	-52.1735	0.0000	-0.1445
8	148.7258	0.0000	-349.1900	0.0000	-0.2961	8	210.0867	0.0000	-329.4765	0.0000	-0.3422
9	225369.465	225369.477	-0.013	5.256	-0.013	9	224218.418	224210.426	-0.009	8.309	-0.009
10	-899.872	-900.756	0.858	724.083	-0.069	10	-960.749	-961.463	0.729	458.087	-0.031
11	-2136.673	-2134.772	2.092	16.407	1.352	11	-2244.424	-2244.445	0.001	614.755	1.723
12	27.5113	-0.1004	-0.0104	107155.594	-0.1958	12	24.0336	-0.0781	-0.0076	107049.138	-0.1564
13	-1.3689	0.0115	0.0377	6897299.313	-0.0231	13	-1.3716	0.0099	0.0292	6742740.188	-0.0645
14	-0.0000	0.0000	0.0200	6996771.563	0.0303	14	0.0000	-0.0000	0.0000	6761706.563	0.0000
15	-62.4746	0.0000	0.0000	-0.0028	650.0303	15	-66.1028	0.0000	0.0000	-0.0010	667.3917
16	-1.6140	0.0000	0.0000	-0.1006	-1.4300	16	-1.4400	0.0000	0.0000	-0.0703	-1.5414
17	0.0000	0.0000	0.0000	0.0115	-3.3645	17	0.0000	0.0000	0.0000	0.0035	-3.7021
18	9.0165	7.7784	7.8186	-0.5432	-0.0092	18	9.6577	4.9566	4.9986	-0.5735	0.0022
19	107.6293	105.1124	105.0922	0.2290	0.0104	19	108.3625	104.9911	105.9783	0.2457	0.0269
20	424.1932	424.6037	-530.7891	-530.1852	225118.877	20	423.6986	424.5370	-528.9635	-530.0354	225023.213
21	0.0001	3.9421	0.0000	3461.1006	881.563	21	0.0001	4.1291	0.0000	2152.4175	859.995
22	77.1797	27.6634	27.5591	-30.6996	-0.0390	22	76.1747	27.3724	27.2197	-30.5732	-0.0384
23	22.6696	22.6663	-1.1455	0.0000	0.0000	23	23.6080	23.5996	-0.7081	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0000	24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000	25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000	26	0.0000	0.0000	0.0000	0.000	0.0000
27	121.9749					27	124.0324				
28	263.8078	127837.5537	0.8609	34.5443	178.7273	28	336.0755	112205.1563	0.8264	35.6024	178.6462
29	3530.5245	9552.2766	31.0915	6324977.5	-174.7697	29	3535.3494	10566.3809	31.2509	7540815.0	-173.8771
30	541.3939	423.5226	11183.8307	71.2831	25.6432	30	578.4336	671.0649	12271.2017	69.5953	25.0392
31	-26.8206	104.2126				31	-26.3015	109.3377			
1	300.0000	226892.994	224615.662	520966.491	1215305.641	1	340.0000	205717.717	224656.398	561697.617	1568517.613
2	9905.5863	8587.3298	21431748.50	20910786.29	3.3300	2	11006.9412	9641.1641	21472741.50	20911086.29	4.2978
3	1244259.000	0.000	1648856.531	0.000	1336308.828	3	1609512.000	0.000	2066237.594	0.000	1685836.953
4	484786.875	0.000	457196.824	0.000	195.2375	4	501349.094	0.000	461766.445	0.000	105.4609
5	5161.015	0.000	-118511.898	0.000	21.2715	5	12944.057	0.000	-131700.297	0.000	17.3308
6	8556.2496	0.0000	9889.5752	0.0000	31.8493	6	9677.8441	0.0000	11099.1465	0.0000	35.1135
7	711.2979	0.0000	444.2439	0.0000	-0.1339	7	116.6911	0.0000	-218.8774	0.0000	-0.1579
8	183.9631	0.0000	-342.4395	0.0000	-0.3086	8	225.8275	0.0000	-317.4045	0.0000	-0.3618
9	224603.121	224603.131	-0.009	11.951	-0.010	9	224642.232	224642.240	-0.007	13.551	-0.009
10	-943.367	-944.349	0.934	86.943	-0.054	10	-1001.908	-1004.617	0.929	-707.981	-0.027
11	-2176.323	-2176.349	0.001	1077.211	1.209	11	-2313.165	-2313.194	0.001	1554.058	0.999
12	26.5116	-0.1119	-0.0096	107131.344	-0.1851	12	23.1744	-0.0765	-0.0073	107021.735	-0.1281
13	-1.5218	0.0074	0.0339	6867741.938	-0.0463	13	-1.5283	0.0052	0.0283	6701041.188	-0.0888
14	0.0000	-0.0000	0.0000	6886728.875	0.0000	14	0.0000	-0.0001	0.0000	6700136.688	0.0000
15	-63.6735	0.0000	0.0000	-0.0035	654.0225	15	-66.9542	0.0000	0.0000	-0.0018	671.0484
16	-1.5661	0.0000	0.0000	-0.1119	-1.4295	16	-1.6169	0.0000	0.0000	-0.0765	-1.5787
17	0.0000	0.0000	0.0000	0.0124	-3.4350	17	0.0000	0.0000	0.0000	0.0032	-3.7911
18	8.0786	6.9977	7.0383	-0.5552	0.0031	18	8.9860	4.4267	4.4687	-0.5900	0.0014
19	107.8070	105.3344	105.3162	0.2409	0.0220	19	108.5202	106.2089	106.1976	0.2562	-0.0161
20	424.1956	424.5912	-529.4801	-530.1936	225115.852	20	424.0047	424.5079	-529.8167	-529.9954	224987.742
21	0.0001	3.9502	0.0000	1966.9281	881.625	21	0.0001	4.2159	0.0000	2194.3628	895.335
22	76.9396	27.5951	27.4412	-30.6635	-0.0389	22	75.9049	27.2920	27.1396	-30.5670	-0.0381
23	22.6582	22.6400	-1.0163	0.0000	0.0000	23	23.7061	23.6997	-0.6207	0.0000	0.0001
24	0.0000	0.0000	0.0000	0.000	0.0000	24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000	25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000	26	0.0000	0.0000	0.0000	0.000	0.0000
27	122.5181					27	124.5365				
28	260.0904	123802.6641	0.8539	34.7852	178.7797	28	357.6200	104505.9229	0.8164	35.9112	179.0019
29	3531.8631	9818.0157	31.1337	6607219.5	-174.9583	29	3536.3571	10966.7056	31.2874	7884333.0	-173.6371
30	550.5709	546.7133	11631.0292	70.8659	25.5012	30	587.9901	647.7694	12498.7201	69.1413	24.9706
31	-28.2117	108.4942				31	-29.6440	109.6227			
1	310.0000	221982.141	224956.520	532545.931	1299540.047	1	350.0000	200413.865	225197.906	569710.617	1663902.594
2	10165.1924	8844.6650	21463399.00	20910855.93	3.5609	2	11310.1218	9983.5259	21480877.75	20911169.25	4.5592
3	1332157.219	0.000	1749075.984	0.000	1419836.484	3	1707794.844	0.000	2177726.813	0.000	1780350.000
4	491168.469	0.000	460833.055	0.000	105.2958	4	501778.984	0.000	458741.949	0.000	105.5129
5	4877.200	0.000	-121903.742	0.000	20.2347	5	15287.158	0.000	-134844.375	0.000	16.3739
6	8824.9192	0.0000	10155.9232	0.0000	32.6605	6	9980.5492	0.0000	11299.1914	0.0000	36.1441
7	562.4136	0.0000	281.0725	0.0000	-0.1435	7	-30.9827	0.0000	-386.2071	0.0000	-0.1557
8	179.7857	0.0000	-335.8781	0.0000	-0.3211	8	241.8029	0.0000	-311.4489	0.0000	-0.3706
9	224943.457	224943.467	-0.009	20.171	-0.009	9	225163.967	225163.975	-0.007	2.994	-0.009
10	-959.635	-959.365	0.931	-14.337	-0.044	10	-969.694	-970.344	0.628	402.194	-0.076
11	-2211.588	-2211.599	0.001	2933.671	1.107	11	-2300.694	-2300.719	0.001	90.092	0.960
12	25.4545	-0.1047	-0.0086	107103.969	-0.1683	12	22.2832	-0.0911	-0.0071	106994.352	-0.1560
13	-1.4623	0.0082	0.0314	6926082.188	-0.0494	13	-1.2888	0.0049	0.0278	6659414.125	-0.0845
14	0.0000	-0.0001	0.0000	6925084.250	0.0000	14	-0.0000	0.0000	0.0000	6658486.813	0.0000
15	-64.7138	0.0000	0.0000	-0.0027	658.4786	15	-67.8728	0.0000	0.0000	-0.0020	676.3059
16	-1.5518	0.0000	0.0000	-0.1047	-1.4668	16	-1.3755	0.0000	0.0000	-0.0911	-1.6169
17	0.0000	0.0000	0.0000	0.0062	-3.5243	17	0.0000	0.0000	0.0000	0.0049	-3.4802
18	7.2042	6.2459	6.3071	-0.5634	-0.0310	18	4.3775	3.8632	3.9081	-0.5979	-0.0302
19	107.9870	105.5564	105.5345	0.2520	-0.0053	19	108.6980	106.4268	106.4169	0.2470	-0.0369
20	424.4483	424.5831	-529.9417	-530.1951	225108.023	20	424.1770	424.5032	-530.5282	-530.0173	224994.859
21	0.0001	3.9938	0.0000	2040.9339	881.960	21	0.0001	4.3174	0.0000	2225.1348	901.609
22	76.4970	27.5739	27.3704	-30.6105	-0.0387	22	75.6262	27.2083	27.0549	-30.5261	-0.0382
23	22.6142	22.6200	-0.9691	0.0000	0.0000	23	23.7177	23.7128	-0.5413	0.0000	0.0001
24	0.0000	0.0000	0.0000	0.000	0.0000	24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000	25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000	26	0.0000	0.0000	0.0000	0.000	0.0000
27	123.0448					27	125.0086				
28	297.5261	119868.0371	0.8647	35.0413	178.8139	28	360.4017	104869.5439	0.8098	36.2426	179.0966
29	3535.1191	10092.9021	31.1744	6903635.0	-174.3392	29	3537.2939	11277.7061	31.3227	8243798.0	-173.1757
30	559.7807	570.6660	11689.0271	70.4548	25.3535	30	597.7360	675.6540	12785.6196	68.6882	24.6952
31	-27.5866	108.7754				31	-29.0745	109.9192			
1	320.0000	216300.484	224149.218	543165.711	1386430.641	1	360.0000	195110.044	225000.242	574952.297	1762321.953
2	10335.6196	9117.6348	21454087.25	20911079.93	3.7989	2	11625.6062	10297.9932	21488205.75	20911255.75	4.0248
3	1423780.000	0.000	1851997.109	0.000	1509855.000	3	1809194.203	0.000	2297256.469	0.000	1877253.703
4	494846.938	0.000	462810.914	0.000	105.3525	4	500772.660	0.000	454014.844	0.000	105.5632
5	8746.572	0.000	-125230.539	0.000	19.2332	5	17789.314	0.000	-137930.297	0.000	15.4702
6	9101.1776	0.0000	10429.5527	0.0000	33.3395	6	10293.2000	0.0000	11608.2729	0.0000	37.1006
7	413.3869	0.0000	114.3165	0.0000	-0.1446	7	-179.6305	0.0000	-555.0845	0.0000	-0.1629
8	194.5857	0.0000	-329.6254	0.0000	-0.3283	8	257.8300	0.0000	-305.7970	0.0000	-0.3845
9	224134.252	224134.242	-0.009	16.179	-0.009	9	224985.975	224985.982	-0.007	5.803	-0.009
10	-971.993	-972.546	0.930	735.491	-0.036	10	-988.118	-988.854	0.825	579.932	-0.070
11	-2206.973	-2207.029	0.001	1305.455	1.054	11	-2331.934	-2331.914	0.000	293.342	0.974
12	24.6788	-0.0996	-0.0081	107074.941	-0.1070	12	21.1600	-0.0752	-0.0070	106981.649	-0.1257
13	-1.4546	0.0064	0.0299	6784415.188	-0.0555	13	-1.2371	-0.0026	0.0275	6598737.875	-0.1031
14	-0.0000	-0.0001	0.0000	6783436.438	0.0000	14	0.0000	-0.0000	0.0000	6597831.375	0.0000
15	-65.4281	0.0000	0.0000	-0.0015	662.9351	15	-68.7457	0.0000	0.0000	-0.0016	682.3938
16	-1.4597	0.0000	0.0000	-0.0996	-1.5041	16	-1.3394	0.0000	0.0000	-0.0752	-1.6648
17	0.0000	0.0000	0.0000	0.0066	-3.6131	17	0.0000	0.0000	0.0000	-0.0026	-3.9966
18	8.1959	5.5823	5.6239	-0.5642	-0.0054	18	3.8253	3.3879	3.4313	-0.5938	0.0310
19	107.1649	105.7732	105.7587	0.2446	0.0353	19	108.8750	106.6440	106.6353	0.2518	-0.0321
20	423.9881	424.5550	-528.6381	-530.1196	225062.969	20	424.5492	424.5046	-529.9609	-530.0305	225003.648
21	0.0001	4.0573	0.0000	2099.1978	885.542	21	0.0001	4.4258	0.0000	2252.9404	908.293
22	76.4371	27.4497	27.2966	-30.5999	-0.0386	22	75.3396	27.1211	26.9695	-30.5035	-0.0383
23	23.7176	23.7269	-0.7902	0.0000	0.0000	23	23.6494	23.6659	-0.4547	0.0000	0.0002
24	0.0000	0.0000	0.0000	0.000	0.0000	24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000	25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000	26	0.0000	0.0000	0.0000	0.000	0.0000
27	123.5537					27	125.4705				
28	316.1606	115992.2871	0.8358	35.3132	178.8902	28	405.1392	101299.4502	0.7949	36.5986	179.1110
29	3534.2670	10174.2849	31.2133	7214490.0	-174.1124	29	3538.1546	11599.3663	31.3585	8631489.0	-173.1275
30	569.0315	595.3888	11951.6196	70.0325	25.2000	30	607.6512	704.7299	13082.0169	68.1776	24.5065
31	-26.9487	109.8557				31	-28.2944	110.2065			

TABLE AP 6-1 (Sheet 5 of 7)
FLIGHT SIMULATED DATA (AC77)

1	370.0000	189809.664	225134.934	593469.259	1863881.484
2	11952.4603	10426.2376	21494812.55	20911345.25	5.1071
3	1913698.734	0.000	2409972.154	0.000	1977577.078
4	495186.047	0.000	447617.297	0.000	105.6121
5	20445.012	0.000	-149960.217	0.000	14.5913
6	10415.6237	0.0000	11926.6148	0.0000	38.1594
7	-726.1216	0.0000	-724.8117	0.0000	-0.1686
8	274.1575	0.0000	-300.2151	0.0000	-0.4006
9	225120.322	225120.330	-0.007	3.608	-0.010
10	-994.440	-994.116	0.029	574.527	-0.018
11	-2363.040	-2363.160	0.003	83.449	1.032
12	20.6942	-0.0705	-0.0049	176928.984	-0.1132
13	-1.2718	0.0095	0.0247	65389930.125	-0.0986
14	0.0000	0.0000	0.0003	6537166.563	0.0305
15	-69.4280	0.0000	0.0000	-0.0015	688.8837
16	-1.7025	0.0000	0.0000	-0.0705	-1.7135
17	0.0000	0.0000	0.0000	0.0095	-4.1127
18	3.3319	2.9413	3.0052	-0.0014	-0.0051
19	109.0439	104.4418	104.8542	0.2533	0.0119
20	424.5224	424.5096	-530.2901	-530.0365	225306.191
21	0.0001	4.5409	0.0003	2277.9767	920.221
22	75.0444	27.0193	26.8791	-30.4449	-0.0178
23	23.1787	23.1762	-0.1483	0.0003	0.0002
24	0.0000	0.0000	0.0000	0.003	0.0303
25	0.0000	0.0000	0.0000	0.000	0.0303
26	0.0000	0.0000	0.0000	0.000	0.0303
27	125.9227				
28	431.7696	97409.3584	0.7825	36.9806	179.1637
29	3538.9543	11931.4552	31.3892	9034.9510.0	-172.8265
30	617.8032	735.1447	13387.9397	67.6656	24.9093
31	-23.6073	110.4956			

1	380.0000	184309.600	224695.604	589321.531	1968685.125
2	12290.7755	10962.1040	21507758.75	20911438.53	5.3941
3	2021496.219	0.000	2530818.844	0.000	2081149.644
4	494141.621	0.000	439538.457	0.000	105.6595
5	23268.982	0.000	-143935.281	0.000	13.7359
6	10947.9910	0.0000	12254.5602	0.0000	39.1771
7	-476.4478	0.0000	-496.7935	0.0000	-0.1765
8	290.6769	0.0000	-294.8298	0.0000	-0.4219
9	224670.279	224670.297	-0.007	1.688	-0.011
10	-1012.900	-1013.111	0.032	-504.329	-0.017
11	-2419.634	-2419.739	0.000	344.566	1.190
12	19.9754	-0.0824	-0.0069	106496.278	-0.1253
13	-1.1537	0.0096	0.0319	6477362.438	-0.1173
14	0.0000	0.0000	0.0003	6636497.750	0.0000
15	-70.1500	0.0000	0.0000	-0.0017	695.1736
16	-1.2710	0.0000	0.0000	-0.0824	-1.7622
17	0.0000	0.0000	0.0000	0.0096	-4.2289
18	2.9987	2.5851	2.6296	-0.0171	-0.0068
19	109.2316	107.0798	107.0737	0.2544	0.0089
20	424.2522	424.4953	-529.5677	-530.0358	224998.340
21	0.0001	4.8621	0.0000	2390.4523	942.065
22	74.7401	26.9359	26.7849	-30.4482	-0.0178
23	23.4239	23.8223	-0.3089	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0303
25	0.0000	0.0000	0.0000	0.000	0.0303
26	0.0000	0.0000	0.0000	0.000	0.0003
27	126.3661				
28	440.1633	96373.4375	0.7698	37.3915	179.2130
29	3539.6936	12273.9424	31.4206	9465154.0	-172.5314
30	626.2445	767.0701	13703.5901	67.1795	24.1006
31	-22.9145	110.7953			

1	390.0000	179289.844	224415.215	594577.203	2076842.828
2	12641.4491	11312.4496	21576110.75	20911535.25	5.6904
3	2132881.219	0.000	2655048.219	0.000	2188105.125
4	488657.734	0.000	429739.191	0.000	105.7054
5	26259.184	0.000	-146857.559	0.000	12.9044
6	11291.0465	0.0000	12593.0881	0.0000	40.2870
7	-624.3083	0.0000	-1065.3837	0.0000	-0.1891
8	307.3767	0.0000	-299.6788	0.0000	-0.4355
9	224399.617	224399.625	-0.007	15.425	-0.013
10	-1053.032	-1053.454	0.034	97.511	-0.015
11	-2425.898	-2425.939	0.000	1367.492	1.174
12	19.2571	-0.0611	-0.0068	106883.594	-0.0695
13	-1.1055	0.0042	0.0355	6418674.750	-0.1253
14	-0.0000	-0.0001	0.0000	6415830.938	0.0303
15	-70.8324	0.0000	0.0000	-0.0012	501.4635
16	-1.2308	0.0000	0.0000	-0.0612	-1.8109
17	0.0000	0.0000	0.0000	0.0042	-4.3653
18	2.9222	2.2569	2.3014	-0.6194	-0.0013
19	109.4108	107.2981	107.2924	0.2690	-0.0041
20	423.9550	424.4439	-529.3005	-530.0114	224990.617
21	0.0001	4.7904	0.0000	2320.4366	965.091
22	74.4271	26.8973	26.6849	-30.4532	-0.0376
23	23.4125	23.4115	-0.2356	0.0000	0.0303
24	0.0000	0.0000	0.0000	0.000	0.0003
25	0.0000	0.0000	0.0000	0.000	0.0303
26	0.0000	0.0000	0.0000	0.000	0.0003
27	126.4014				
28	491.2418	91009.7070	0.7561	37.8349	179.2577
29	3540.3355	12627.5617	31.4507	9918695.0	-172.2208
30	639.0547	809.7010	14030.1191	66.5468	23.8787
31	-22.7156	111.1012			

1	400.0000	173908.937	225259.734	599303.547	2188469.000
2	13005.0078	11675.8184	21510937.25	20911435.25	5.9964
3	2247351.000	0.000	2727716.656	0.000	2298560.656
4	481677.688	0.000	418210.922	0.000	105.7499
5	29417.352	0.000	-149729.484	0.000	12.0962
6	11665.7826	0.0000	12942.9098	0.0000	41.4713
7	-771.5869	0.0000	-1214.3909	0.0000	-0.1829
8	324.3946	0.0000	-284.7405	0.0000	-0.4503
9	225244.402	225244.414	-0.007	-9.365	-0.015
10	-988.675	-989.365	0.040	1062.030	-0.014
11	-2433.916	-2433.976	0.000	-1304.594	1.599
12	18.5527	-0.0644	-0.0069	106830.992	-0.0878
13	-1.0752	0.0081	0.0196	6355987.063	-0.1261
14	0.0000	0.0001	0.0000	6355186.125	0.0000
15	-71.5351	0.0000	0.0000	-0.0012	507.7534
16	-1.2012	0.0000	0.0000	-0.0664	-1.8595
17	0.0000	0.0000	0.0000	0.0081	-4.4616
18	2.2074	1.9772	2.0223	-0.6191	-0.0034
19	109.5910	107.5171	107.5121	0.2517	-0.0012
20	424.4491	424.4743	-530.0748	-530.0346	224987.797
21	0.0001	4.9250	0.0000	2338.7891	989.307
22	74.1046	26.7343	24.1948	-30.4498	-0.0375
23	23.7681	23.7676	-0.1831	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0003
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	127.2792				
28	524.6243	87705.2656	0.7419	38.3140	179.2960
29	3541.0201	12994.0834	31.4796	10399448.0	-171.8921
30	650.2762	836.2814	14368.2979	65.9737	23.8617
31	-21.5112	111.4149			

1	410.0000	169600.688	225607.842	603577.711	2303692.934
2	13382.6715	12053.3674	21515315.75	20911740.00	6.3121
3	2365636.969	0.000	2913944.813	0.000	2412727.375
4	473227.703	0.000	405911.343	0.000	105.7939
5	32745.869	0.000	-152553.349	0.000	11.3112
6	12013.4800	0.0000	13305.4099	0.0000	43.0494
7	-918.3835	0.0000	-1407.7367	0.0000	-0.1963
8	341.3817	0.0000	-280.1297	0.0000	-0.4747
9	225591.781	225591.801	-0.007	-2.455	-0.017
10	-1028.709	-1029.544	0.043	520.933	-0.910
11	-2485.124	-2485.098	0.000	-447.539	1.763
12	17.7735	-0.0911	-0.0045	104799.094	-0.1207
13	-1.0142	-0.0025	0.0431	6265346.688	-0.1496
14	0.0000	0.0000	0.0000	6266570.313	0.0300
15	-72.3267	0.0000	0.0000	-0.0016	516.8535
16	-1.1629	0.0000	0.0000	-0.0911	-1.9259
17	0.0000	0.0000	0.0000	-0.0025	-4.6197
18	1.9372	1.7447	1.7902	-0.6311	-0.0052
19	109.7719	107.7367	107.7323	0.2415	0.0029
20	424.7225	424.4783	-531.1511	-530.0675	225302.859
21	0.0001	5.0665	0.0003	2355.2029	1036.215
22	73.7723	26.6290	26.4295	-30.4276	-0.0374
23	23.6043	23.6041	-0.1047	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0303
25	0.0000	0.0000	0.0000	0.003	0.0303
26	0.0000	0.0000	0.0000	0.000	0.0303
27	127.6502				
28	540.8542	84450.7412	0.7264	38.8167	179.3259
29	3541.6238	13373.6818	31.5071	10910942.0	-171.5621
30	661.9930	876.1714	14719.5579	64.3451	23.3872
31	-20.8083	111.7375			

1	420.0000	167290.324	224932.760	607476.625	2422650.259
2	13774.5769	12445.5044	21519322.75	20911444.53	6.4181
3	2487685.125	0.000	3048867.688	0.000	2530700.313
4	463307.719	0.000	390070.469	0.000	105.8144
5	36246.148	0.000	-155332.531	0.000	10.5689
6	12394.6155	0.0000	13681.0346	0.0000	44.3165
7	-1065.4217	0.0000	-1540.6318	0.0000	-0.2307
8	358.6692	0.0000	-275.8372	0.0000	-0.4957
9	224916.188	224916.188	-0.008	0.355	-0.018
10	-1064.327	-1065.010	0.046	250.906	-0.004
11	-2515.861	-2515.861	0.000	443.170	1.474
12	16.9722	-0.0824	-0.0057	106749.281	-0.0527
13	-0.9511	0.0033	0.0461	6176648.375	-0.1549
14	0.0000	0.0000	0.0000	6179918.563	0.0000
15	-73.0005	0.0000	0.0000	-0.0019	525.9554
16	-1.1044	0.0000	0.0000	-0.0824	-1.9922
17	0.0000	0.0000	0.0000	0.0033	-4.7298
18	1.7208	1.5447	1.6007	-0.6409	-0.0013
19	109.9560	107.9571	107.9532	0.2733	-0.0031
20	424.0999	424.4803	-530.3376	-530.1068	224920.594
21	0.0001	5.2148	0.0000	2370.1767	1013.839
22	73.4299	26.5184	26.3478	-30.4144	-0.0372
23	23.3799	23.3799	-0.0277	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0003
25	0.0000	0.0000	0.0000	0.000	0.0303
26	0.0000	0.0000	0.0000	0.000	0.0000
27	128.0448				
28	600.2417	81244.8037	0.7102	39.4956	179.3465
29	3542.1966	13767.1094	31.5333	11455486.0	-171.1664
30	674.2469	914.9199	15044.5813	64.6783	23.1132
31	-20.0837	112.0704			

1	430.0000	157986.140	224913.023	611079.766	2565474.156
2	14180.6947	12841.5027	21523038.75	20911961.00	6.9744
3	2613567.719	0.000	3187606.531	0.000	2632650.750
4	453915.434	0.000	373395.427	0.000	105.8751
5	39919.465	0.000	-158070.453	0.000	9.8399
6	12784.6337	0.0000	14069.2542	0.0000	45.8003
7	-1212.4434	0.0000	-1754.3957	0.0000	-0.2157
8	376.1229	0.0000	-271.8193	0.0000	-0.5151
9	224896.297	224896.301	-0.005	2.104	-0.021
10	-1059.245	-1059.924	0.040	815.203	-0.003
11	-2529.167	-2529.236	-0.000	-172.274	1.914
12	16.3622	-0.0804	-0.0048	104708.469	-0.0564
13	-0.9171	0.0086	0.0496	6084010.000	-0.1553
14	0.0000	0.0000	0.0000	6083284.813	0.0000
15	-73.6947	0.0000	0.0000	-0.0017	535.0573
16	-1.0723	0.0000	0.0000	-0.0804	-2.0546
17	0.0000	0.0000	0.0000	0.0086	-4.9361
18	1.5544	1.4048	1.4552	-0.6443	-0.0044
19	110.1373	108.1786	108.1748	0.2700	0.0071
20	424.1144	424.4481	-530.2727	-530.1146	224919.121
21	0.0001	5.3492	0.0000	2344.0145	1021.781
22	73.0772	26.4010	26.2524	-30.4062	-0.0371
23	23.3075	23.3075	0.0181	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0003
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0303
27	128.4736				
28	643.0088	78095.3301	0.6928	40.0251	179.3544
29	3542.7504	14174.2920	31.5582	12034644.0	-170.7486
30	687.1512	957.6092	15442.9499	63.9675	22.8167
31	-19.3645	112.4149			

1	440.0000	152684.750	225392.531	614483.656	2672301.844
2	14601.6113	13272.2274	21526559.25	20912078.00	7.3221
3	2743681.094	0.000	3330296.781	0.000	2774736.250
4	439054.906	0.000	354983.413	0.000	105.9143
5	43769.221	0.000	-160779.139	0.000	9.0312
6	13196.6555	0.0000	14471.2059	0.0000	47.4915
7	-1356.4074	0.0000	-1927.9101	0.0000	-0.2273
8	393.7471	0.0000	-269.2168	0.0000	-0.5444
9	225375.203	225375.209	-0.004	-2.990	-0.021
10	-1069.079	-1069.765	0.051	121.588	0.007
11	-2581.671	-2581.620	-0.000	-333.149	2.149
12	15.7962	-0.0841	-0.0040	106667.656	-0.0810
13	-0.8698	-0.0048	0.0532	5993371.688	-0.1802
14	-0.0000	0.0000	0.0003	5992655.063	0.0000
15	-74.2649	0.0000	0.0000	-0.0019	544.1591
16	-1.0360	0.0000	0.0000	-0.0841	-2.1249
17	0.0000	0.0000	0.0000	-0.0048	-5.0943
18	1.4417	1.3105	1.3572	-0.6563	0.0063
19	110.3221	108.4008	108.3975	0.2718	-0.0022
20	424.0427	424.4330	-530.3404	-530.1192	225310.906
21	0.0001	5.5298	0.0000	2307.0871	1028.594
22	72.7138	26.2874	26.1323	-30.3944	-0.0369
23	23.2369	23.2368	0.0941	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0003
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	128.9769				
28	689.5788	74997.1025	0.6747	40.7031	179.3638
29	3543.3039	14595.9346	31.5817	12650211.0	-170.3387
30	700.8858	1004.1961	15855.9820	63.2939	22.4931
31	-18.6429	112.7747			

TABLE AP 6-1 (Sheet 6 of 7)
FLIGHT SIMULATED DATA (AC77)

1	450.0000	147189.514	224425.932	6177?4.094	2833275.253
2	15037.4895	13?09?.3???	21529??0.?5	20912199.25	7.6809
3	2877544.531	0.000	3677079.063	0.000	2909120.313
4	424749.894	0.000	334435.684	0.000	105.9516
5	47796.149	0.000	-163435.328	0.000	9.3955
6	13619.4295	0.0000	14?47.6251	0.0000	48.9066
7	-1503.3461	0.0000	-2101.9426	0.0000	-0.7359
8	411.6491	0.0000	-264.9169	0.0000	-0.5667
9	224408.191	224408.187	-0.004	-0.839	-0.024
10	-10?00.452	-10?41.172	0.055	169.0?5	0.011
11	-2598.265	-2598.314	-0.000	-159.?39	2.189
12	15.1490	-0.0613	-0.0045	176624.?40	-0.0542
13	-0.8?61	0.0?49	0.0550	59027??1.313	-0.1807
14	-0.0000	0.0000	0.0000	59?2023?.313	0.0309
15	-74.9953	0.0000	0.0033	-0.?009	553.2609
16	-0.?844	0.0000	0.0?03	-0.?613	-2.1919
17	0.0000	0.?90?	0.0000	0.0?45	-5.2525
18	1.3?48	1.2549	1.3940	-0.?629	-0.0916
19	110.5?90	108.6244	108.6215	0.2?63	-0.0931
20	424.0399	424.4?09	-529.2151	-530.0972	224990.434
21	0.0001	5.6945	0.0000	2449.8008	1028.504
22	72.1394	26.1547	26.0?71	-30.3??0	-0.0368
23	23.0468	23.0464	0.1432	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000?	0.0000
25	0.0000	0.0000	0.0000	0.000?	0.0000
26	0.0000	0.0000	0.0000	0.000?	0.0000
27	129.2752				
28	7?C.4129	71947.0879	0.6544	61.4468	179.3109
29	3543.4729	15031.7333	31.6041	1?307?902.0	-169.8721
30	715.5961	1054.7492	16264.1495	62.3794	22.1377
31	-17.9195	113.1510			

1	460.0000	142101.789	223955.816	621117.313	2938540.561
2	15440.?461	14149.4573	21531660.25	20912?7?.25	8.0515
3	3015?91.344	0.000	3628098.844	0.000	3063968.188
4	4?4994.043	0.000	312944.922	0.000	105.9878
5	52002.594	0.000	-166070.109	0.000	7.7217
6	14057.7217	0.0000	15119.2?44	0.0000	50.7027
7	-1447.5497	0.0000	-2276.2431	0.0000	-0.2495
8	429.6436	0.0000	-262.1349	0.0000	-0.5954
9	223937.652	223937.658	-0.004	2.565	-0.026
10	-1102.147	-1102.?7?	0.057	-179.?20	0.016
11	-2629.?99	-2629.?40	-0.000	271.?33	2.199
12	14.5641	-0.0001	-0.0040	106576.953	-0.0435
13	-0.?572	-0.0017	0.0170	5777221.500	-0.1?99
14	0.0000	0.0000	0.0000	577?6564.375	0.0000
15	-75.4??4	0.0000	0.0000	-0.0?04	565.3443
16	-0.9567	0.0000	0.0000	-0.0601	-2.2?69
17	0.0000	0.0000	0.0000	-0.0017	-5.4579
18	1.3638	1.2469	1.2943	-0.6?2?	-0.0010
19	110.4972	108.8495	108.8466	0.2822	0.0327
20	423.8325	424.4049	-529.3635	-530.0434	224953.924
21	0.0001	5.8489	0.0000	2422.5436	1028.504
22	71.9534	26.0237	25.?7?7	-30.?775	-0.0365
23	22.8848	22.8841	0.1944	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000?	0.0000
25	0.0000	0.0000	0.0000	0.000?	0.0000
26	0.0000	0.0000	0.0000	0.000?	0.0000
27	129.6688				
28	7?4.0186	69942.?729	0.6332	42.2655	179.2500
29	3544.4?97	15483.5441	31.6249	1409?03?4.0	-169.3639
30	731.4349	1109.9827	16688.6?93	61.4835	21.?444
31	-17.1948	113.5477			

1	470.0000	136817.049	224121.904	624577.055	3078259.313
2	15?6C.0512	14630.?600	21537030.?5	20912456.?5	8.4343
3	3158?58.031	0.000	3783520.906	0.000	3103463.594
4	391803.309	0.000	249310.855	0.000	106.0228
5	5?391.404	0.000	-166?77.?04	0.000	7.0696
6	14513.8975	0.0000	15?68.5710	0.0000	52.?009
7	-1790.2419	0.0000	-2450.4809	0.0000	-0.2566
8	448.2039	0.0000	-259.4??8	0.0000	-0.6261
9	224103.426	224103.476	-0.004	-9.006	-0.029
10	-1091.180	-1091.941	0.059	-?67.?06	0.019
11	-2667.451	-2667.447	-0.001	-472.095	?.?09
12	13.9?40	-0.0632	-0.0041	106527.042	-0.0103
13	-0.?354	0.0014	0.0588	5651?08.750	-0.2046
14	0.0000	0.0000	0.0000	565?04?.5?3	0.0000
15	-76.0763	0.0000	0.0000	-0.0098	577.8295
16	-0.9402	0.0000	0.0000	-0.0632	-2.3628
17	0.0000	0.0000	0.0000	0.0014	-5.6625
18	1.3993	1.2828	1.3306	-0.6807	0.0039
19	110.8987	109.0772	109.0743	0.?792	-0.0010
20	423.7638	424.3434	-528.8404	-529.?9?7	224972.805
21	0.0001	6.0449	0.0000	2436.5134	1028.347
22	71.5560	25.8473	25.7408	-30.3676	-0.0365
23	22.6751	22.6743	0.2166	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000?	0.0000
25	0.0000	0.0000	0.0000	0.000?	0.0000
26	0.0000	0.0000	0.0000	0.000?	0.0000
27	130.0589				
28	?57.2553	69973.2149	0.6106	43.1727	179.1509
29	3545.1567	15953.0006	31.6452	14758?42?.0	-168.8?3?
30	748.?505	1171.0536	17191.?175	60.4988	21.3035
31	-16.4672	113.9711			

1	480.0000	?1520.969	224844.779	628307.641	3222614.844
2	16451.1631	15121.9017	21540497.?5	20917592.00	8.8298
3	3106260.094	0.000	3943535.156	0.000	3327813.469
4	?71190.934	0.000	263932.688	0.000	106.0564
5	609A?.617	0.000	-171260.918	0.000	6.4389
6	14990.5918	0.0000	16238.0?24	0.0000	54.9992
7	-1937.8646	0.0000	-2676.0429	0.0000	-0.2773
8	467.0997	0.0000	-257.2002	0.0000	-0.6598
9	224825.730	224825.736	-0.004	4.382	-0.029
10	-1132.399	-1134.611	0.059	-165.159	0.021
11	-2696.986	-2697.149	-0.001	353.139	2.133
12	12.7911	-0.1845	-0.0042	106473.693	-0.1581
13	-0.4939	0.0134	0.0586	5?12346.?03	-0.2026
14	0.0000	0.0000	0.0000	5?11757.125	0.0000
15	-77.3670	0.0000	0.0000	-0.0?22	591.3552
16	-0.8965	0.0000	0.0000	-0.1545	-2.4562
17	0.0000	0.0000	0.0000	0.0135	-5.8854
18	1.4196	1.3691	1.4083	-0.6873	-0.0049
19	111.0424	109.3049	109.3036	0.2591	0.0193
20	423.9124	424.3440	-530.3590	-529.9838	224937.016
21	0.0001	6.2398	0.0000	2644.7471	1027.738
22	71.1442	25.7490	25.?992	-30.3570	-0.0363
23	21.8429	21.8417	0.2522	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	130.4432				
28	925.0889	69026.1172	0.5862	44.1862	179.0053
29	3545.9389	16442.6?41	31.6664	1556A0310.0	-168.1782
30	767.4243	1239.2196	17596.0615	59.4971	20.8042
31	-15.7344	114.4251			

1	490.0000	126727.573	223544.203	632403.?66	3371821.156
2	16966.5461	15637.2706	21545134.50	20912?33.00	9.2186
3	3458443.531	0.000	4108356.313	0.000	3477243.938
4	353116.?46	0.000	236755.150	0.000	136.0859
5	65732.846	0.000	-173924.?03	0.000	5.8205
6	15490.2201	0.0000	16729.9385	0.0000	56.9760
7	-2083.5672	0.0000	-2811.3237	0.0000	-0.2553
8	485.8594	0.0000	-255.4??8	0.0000	-0.6901
9	223524.990	223524.996	-0.004	-?.?29	-0.029
10	-1119.374	-1120.732	0.057	-52.171	0.031
11	-2707.319	-2707.442	-0.001	-427.153	2.092
12	11.1709	-0.1119	-0.0043	106415.658	-0.0969
13	-0.5?C9	0.0120	0.0571	5356428.?03	-0.2119
14	0.0000	0.0000	0.0000	5?93477.875	0.0309
15	-78.9090	0.0000	0.0000	-0.0?11	636.5427
16	-0.?828	0.0000	0.0000	-0.1119	-2.5597
17	0.0000	0.0000	0.0000	0.0129	-6.1324
18	1.5747	1.4513	1.4984	-0.6940	-0.0007
19	111.2766	109.5374	109.5338	0.2473	0.0036
20	423.?798	424.3469	-527.4576	-529.0631	224838.711
21	0.0001	6.4347	0.0000	2455.9823	1027.103
22	70.?258	25.5963	25.6315	-30.3453	-0.0361
23	20.5834	20.5807	0.3623	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000?	0.0000
25	0.0000	0.0000	0.0000	0.000?	0.0000
26	0.0000	0.0000	0.0000	0.000?	0.0000
27	130.?247				
28	1000.?001	69086.6?53	0.5598	45.3?80	170.8207
29	3546.0365	16956.1404	31.6916	164400104.0	-167.4717
30	786.6118	1315.0872	18045.1314	64.2007	20.2403
31	-14.9908	114.9079			

1	500.0000	121066.274	212373.963	636921.689	3526076.188
2	17494.5378	16185.1964	21544?89.25	20912879.50	9.8612
3	3616104.969	0.000	427817?.875	0.000	3631955.219
4	331495.371	0.000	207677.672	0.000	134.1198
5	70A83.014	0.000	-176380.803	0.000	5.2166
6	16001.0047	0.0000	17232.3?64	0.0000	56.4344
7	-2242.1441	0.0000	-3005.?266	0.0000	-0.2739
8	504.0751	0.0000	-255.5121	0.0000	-0.6926
9	212355.467	212355.471	-0.004	-31.044	-0.031
10	-1028.926	-1029.637	0.057	-411.?48	0.037
11	-2606.054	-2606.187	-0.001	-2387.349	1.937
12	10.3479	-0.0514	-0.0045	1063?7.443	-0.0636
13	-0.4911	0.0114	0.0574	51?4410.185	-0.2262
14	0.0000	0.0000	0.0000	5199??4.563	0.0303
15	-?9.6978	0.0000	0.0000	-0.0094	621.7359
16	-0.?173	0.0000	0.0000	-0.0514	-2.6432
17	0.0000	0.0000	0.0000	0.0115	-6.1?94
18	1.6814	1.5536	1.6025	-0.7031	-0.0101
19	111.4715	109.7674	109.7637	0.2??8	-0.0266
20	426.4137	424.3674	-694.0014	-529.5375	224714.959
21	0.0001	6.6371	0.0000	2466.3??2	1026.459
22	70.2842	24.4420	25.2975	-30.3325	-0.0359
23	20.1028	20.0949	0.4305	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000?	0.0000
25	0.0000	0.0000	0.0000	0.000?	0.0000
26	0.0000	0.0000	0.0000	0.000?	0.0000
27	131.2028				
28	1083.8696	57?23.3940	0.5329	46.5997	178.1891
29	3547.8700	17481.6?14	31.6962	173639314.0	-166.4862
30	811.?518	1399.0021	18588.1111	66.8766	19.6069
31	-14.2535	115.4158			

1	51C.0000	116312.235	196229.027	641884.500	3683327.563
2	18003.8691	16674.4343	21554913.25	20913?31.25	10.0975
3	3??A580.15A	0.000	4452?20.668	0.000	3791889.656
4	30A?42.402	0.000	17A408.551	0.000	136.1494
5	75812.?49	0.000	-179936.?26	0.000	4.6627
6	16491.1584	0.0000	17713.5642	0.0000	54.2755
7	-2409.6310	0.0000	-3209.1940	0.0000	-0.2872
8	521.6678	0.0000	-255.8263	0.0000	-0.6705
9	196211.305	196211.311	-0.005	14.114	-0.033
10	-1038.423	-1037.641	0.059	-?0.159	0.042
11	-2423.875	-2424.014	-0.001	1?16.008	1.891
12	10.0018	0.9750	-0.0045	106?97.901	0.1168
13	-0.4137	0.0129	0.0547	5007221.188	-0.2285
14	-0.0000	-0.0000	0.0000	500A?52.938	0.0309
15	-79.8814	0.0000	0.0000	0.0005	639.5913
16	-0.6422	0.0000	0.0000	0.0759	-2.7815
17	0.0000	0.0000	0.0000	0.0128	-6.6615
18	1.7814	1.6498	1.6993	-0.7078	-0.0315
19	111.6704	109.9972	109.9933	0.3030	-0.0117
20	427.3831	424.4525	-459.0994	-527.9212	224073.448
21	0.0001	6.8275	0.0000	2481.9912	1025.849
22	69.8396	25.2809	25.1371	-30.3146	-0.0357
23	20.1207	20.1245	0.4492	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000?	0.0000
25	0.0000	0.0000	0.0000	0.000?	0.0000
26	0.0000	0.0000	0.0000	0.000?	0.0000
27	131.5771				
28	1164.4616	56589.6777	0.5943	47.9946	178.3286
29	3549.0252	17985.1442	31.7084	1828?4894.0	-165.8499
30	835.0847	1488.0799	19075.5166	55.4939	18.9233
31	-13.5642	115.9285			

1	520.0000	111827.102	189705.727	647339.?36	3849402.781
2	18501.7436	17172.1543	21560526.00	20913188.50	10.1573
3	3945?47.094	0.000	4632407.188	0.000	3956?76.844
4	283322.170	0.000	143504.314	0.000	136.1776
5	81113.450	0.000	-181500.645	0.000	4.1362
6	16970.0071	0.0000	18183.2791	0.0000	54.4119
7	-2571.3217	0.0000	-3407.6249	0.0000	-0.2601
8	538.5669	0.0000	-257.0471	0.0000	-0.6618
9	189188.732	189188.734	-0.005	-51.019	-0.035
10	-903.981	-901.446	0.056	-611.296	0.044
11	-2369.675	-2369.539	-0.002	-3?14.285	2.015
12	11.7394	0.2329	-0.0046	106?28.157	0.2514
13	-0.5295	-0.0121	0.0657	4817911.438	-0.2639
14	-0.0000	0.0000	0.0000	4817468.563	0.0307
15	-78.0990	0.0000	0.0000	0.0013	657.4539
16	-0.5934	0.0000	0.0000	0.2125	-2.8998
17	0.0000	0.0000	0.0000	-0.0121	-6.9438
18	1.9279	1.7899	1.8388	-0.7176	0.0254
19	111.8719	110.2266	110.2223	0.2732	0.0039
20	429.4492	424.5795	-440.5176	-525.6194	223153.459
21	0.0001	7.0102	0.0000	2494.9544	1025.263
22	69.3788	25.1135	24.9704	-30.3029	-0.0355
23	22.2064	22.2002	0.5894	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000?	0.0000
25	0.0000	0.0000	0.0000	0.000?	0.0000
26	0.0000	0.0000	0.0000	0.000?	0.0000
27	131.9470				
28	1258.7356	52130.1974	0.4765	48.2921	177.9777
29	3550.4251	18481.7375	31.7182	192092124.0	-164.9644
30	861.6698	1547.0662	19553.8496	53.9685	18.1504
31	-12.9144	116.4672			

TABLE AP 6-1 (Sheet 7 of 7)
FLIGHT SIMULATED DATA (AC77)

1	530.0000	107467.907	105531.629	653554.039	4018221.563
2	18997.7442	17668.1011	21564902.25	20913350.50	11.0395
3	4117979.313	0.000	4016549.430	0.000	4126092.008
4	256893.093	0.000	100330.996	0.000	106.2045
5	86585.266	0.000	-184079.109	0.000	3.5509
6	17450.0395	0.0000	18634.4263	0.0309	55.5601
7	-2711.1102	0.0000	-3504.9602	0.0000	-0.2391
8	555.7443	0.0000	-258.6934	0.0000	-0.7006
9	185515.537	185515.543	-0.005	-166.094	-0.043
10	-698.469	-701.739	0.071	-481.617	0.046
11	-2340.033	-2339.922	-0.002	-13166.753	2.059
12	13.0199	-0.2851	-0.0046	106163.412	-0.3368
13	-0.3213	-0.0098	0.0787	46278605.629	-0.2657
14	0.0000	0.0003	0.0000	46278274.129	0.0007
15	-77.3666	0.0000	0.0000	-0.0016	675.3165
16	-0.5870	0.0000	0.0000	-0.2853	-3.0181
17	0.0000	0.0000	0.0000	-0.0094	-7.2257
18	2.1753	2.0230	2.0727	-0.7226	0.0045
19	112.0778	110.4582	110.4534	0.2167	0.1300
20	430.3342	424.7418	-431.0964	-925.0925	222191.760
21	0.0001	7.1882	0.0000	2514.0032	1024.692
22	66.9059	24.9997	24.7973	-10.2853	-0.0353
23	23.7368	23.7310	0.5930	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	132.3125				
28	1353.5122	49787.3643	0.4482	50.7860	177.4442
29	3552.9307	18970.0261	31.7267	201985804.0	-163.9229
30	893.4069	1703.7095	20032.4219	52.1591	17.2218
31	-12.2990	117.0659			
1	540.0000	103164.396	104510.348	660734.492	4191845.563
2	19516.0623	18186.2271	21574250.00	20913518.25	11.4052
3	4294949.063	0.000	5005559.125	0.000	4302039.750
4	229028.051	0.000	71732.910	0.000	106.2302
5	92231.416	0.000	-186673.703	0.000	3.0517
6	17949.0308	0.0000	19143.8237	0.0000	57.5377
7	-2870.8914	0.0000	-3703.7946	0.0000	-0.3619
8	573.7101	0.0000	-260.0937	0.0000	-0.7267
9	184491.965	184491.971	-0.005	117.911	-0.039
10	-1160.386	-1161.967	0.056	741.620	0.035
11	-2330.210	-2330.229	-0.001	9144.412	1.545
12	7.7968	-0.1329	-0.0046	106098.667	0.0063
13	-0.4020	0.0018	0.0560	44392797.875	-0.2555
14	0.0000	-0.0002	0.0000	44384959.688	0.0000
15	-82.1950	0.0000	0.0000	-0.0009	693.1791
16	-0.6574	0.0000	0.0009	-0.1329	-3.1364
17	0.0000	0.0000	0.0000	0.0018	-7.5078
18	2.3948	2.2315	2.2815	-0.7736	0.0101
19	112.2876	110.6937	110.6885	0.3606	0.0739
20	431.2159	424.9139	-427.8413	-520.5514	221144.922
21	0.0001	7.3702	0.0000	2533.7007	1024.108
22	66.4210	24.7993	24.6178	-30.2650	-0.0351
23	18.8043	18.7992	0.4722	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	132.6735				
28	1459.5652	47438.9263	0.4170	52.4774	176.0142
29	3554.6103	19478.9854	31.7358	211788528.0	-162.7198
30	928.9747	1837.0268	20534.2769	50.1374	16.1399
31	-11.6675	117.7022			
1	550.0000	98897.931	103135.402	668774.977	4370523.313
2	20055.4021	18725.3816	21582464.00	20913691.25	11.9747
3	4477017.438	0.000	5199524.313	0.000	4482510.000
4	199462.623	0.000	32816.627	0.000	106.2547
5	98060.486	0.000	-189282.219	0.000	2.9501
6	18467.3401	0.0000	19651.7006	0.0000	59.5731
7	-3040.8297	0.0000	-3994.3561	0.0000	-0.2840
8	592.1476	0.0000	-261.7257	0.0000	-0.7600
9	183118.512	183118.518	-0.005	-69.557	-0.042
10	-873.025	-868.977	0.066	-87.468	0.036
11	-2336.174	-2336.166	-0.001	-5206.307	1.658
12	10.1690	0.3502	-0.0045	106033.922	0.3739
13	-0.3682	0.0037	0.0637	42499990.063	-0.2678
14	-0.0000	0.0001	0.0000	42496895.250	0.0000
15	-79.6368	0.0000	0.0000	0.0021	711.0918
16	-0.6160	0.0000	0.0000	0.3502	-3.2547
17	0.0000	0.0000	0.0002	0.0037	-7.7899
18	2.4212	2.4473	2.4975	-0.7309	-0.0059
19	112.5004	110.9177	110.9266	0.2719	0.0080
20	430.7607	425.0715	-425.1050	-518.0471	220151.625
21	0.0001	7.5559	0.0000	2555.7576	1023.512
22	67.9235	24.5720	24.4319	-30.2421	-0.0348
23	21.4950	21.4886	0.4303	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	131.0305				
28	1578.1131	45097.9048	0.3854	54.3943	176.0056
29	3557.4349	20005.4745	31.7443	222708090.0	-161.2004
30	970.6631	1994.8288	21058.0804	47.7747	14.8304
31	-11.0233	118.1928			
1	560.0000	96852.319	102997.840	678016.813	4356340.250
2	20006.0173	19275.8823	21591884.50	20913869.75	12.4783
3	4464330.813	0.000	5398641.688	0.000	4468534.625
4	168313.752	0.000	-8057.236	0.000	106.2702
5	104076.670	0.000	-191909.256	0.000	2.0661
6	19001.2227	0.0000	20175.7168	0.0000	62.1902
7	-3184.2766	0.0000	-4179.9335	0.0000	-0.3356
8	611.2038	0.0000	-263.7270	0.0000	-0.7993
9	182980.057	182980.061	-0.004	3.508	-0.044
10	-987.374	-987.936	0.064	-17.527	0.031
11	-2351.524	-2351.454	-0.701	262.683	1.521
12	10.3579	-0.0126	-0.0044	105947.459	0.0237
13	-0.3501	-0.0053	0.0638	3966413.688	-0.2629
14	0.0000	0.0000	0.0003	3966177.375	0.0000
15	-79.6184	0.0000	0.0000	-0.0002	736.9456
16	-0.6326	0.0000	0.0009	-0.9326	-3.4201
17	0.0000	0.0000	0.0000	-0.0099	-8.1844
10	2.9619	2.7705	2.8210	-0.7163	-0.0017
19	112.7173	111.1736	111.1673	0.3393	0.0169
20	430.9400	425.2142	-424.6060	-519.6160	219101.641
21	0.0001	7.7397	0.0000	2581.2996	1022.922
22	67.4132	24.3776	24.2377	-30.2162	-0.0348
23	21.0617	21.8966	0.5191	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	133.3036				
28	1700.0610	42810.3052	0.3517	56.5306	174.7776
29	3561.5701	20536.7952	31.7527	234187050.0	-159.9004
30	1024.3949	2196.0559	21594.0625	44.0066	13.1216
31	-10.4052	119.1762			
1	570.0000	90408.743	103349.430	688778.941	4743401.750
2	21100.8113	19850.5879	21692830.75	20914054.00	12.9964
3	4857120.500	0.000	5603120.188	0.000	4862249.063
4	135774.746	0.000	-50770.625	0.000	106.3308
5	110289.004	0.000	-194555.703	0.000	1.6558
6	19560.4109	0.0000	20724.9197	0.0000	65.2405
7	-3322.2562	0.0000	-4361.9214	0.0000	-0.3549
8	631.4965	0.0000	-265.5214	0.0000	-0.8429
9	183325.418	183325.424	-0.004	5.347	-0.045
10	-997.307	-997.452	0.062	235.273	0.024
11	-2368.417	-2368.492	-0.001	316.823	1.347
12	10.7193	-0.0065	-0.0043	105860.992	0.0454
13	-0.3099	0.0060	0.0622	3682700.719	-0.2812
14	0.0000	-0.0000	0.0000	3682602.969	0.0000
15	-79.7353	0.0000	0.0000	-0.0001	752.0569
16	-0.6712	0.0000	0.0000	-0.0065	-3.5856
17	0.0000	0.0000	0.0000	0.0060	-8.5789
18	3.3539	3.1430	3.1937	-0.7402	-0.0032
19	112.9388	111.4196	111.4124	0.3117	-0.0019
20	431.2918	425.3551	-425.0612	-513.3082	210260.453
21	0.0001	7.9252	0.0000	2610.6324	1022.327
22	66.8899	24.1757	24.0368	-30.1859	-0.0341
23	21.8833	21.0791	0.4686	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	133.7332				
28	1854.3363	40547.5459	0.3160	59.0053	173.0381
29	3567.4841	21076.1372	31.7615	246526796.0	-157.2334
30	1093.8029	2455.0193	22157.3049	41.0392	10.0180
31	-9.7898	120.0120			
1	580.0000	86167.950	102357.889	701335.367	4930064.750
2	21781.4993	20451.2236	21615577.00	20914244.25	13.5295
3	5055627.813	0.000	5813224.313	0.000	5060000.875
4	101889.864	0.000	-95280.430	0.000	106.3225
5	116710.754	0.000	-197219.121	0.000	1.1543
6	20146.9221	0.0000	21301.3767	0.0000	63.0827
7	-3453.6318	0.0000	-4539.3201	0.0000	-0.4645
8	653.0801	0.0000	-267.1403	0.0000	-0.8058
9	182338.203	182338.209	-0.004	188.942	-0.045
10	-1244.087	-1244.392	0.060	185.980	0.014
11	-2372.337	-2372.335	-0.001	14415.111	1.159
12	9.9709	-0.0156	-0.0041	105774.508	0.1184
13	-0.4215	-0.0001	0.0596	3399147.750	-0.2688
14	0.0000	-0.0003	0.0000	3399028.531	0.0000
15	-79.9106	0.0000	0.0000	-0.0001	788.7629
16	-0.7102	0.0000	0.0000	-0.0186	-3.7517
17	0.0000	0.0000	0.0000	-0.0001	-8.9735
18	3.7992	3.5669	3.6178	-0.7454	-0.0003
19	113.1650	111.6499	111.6618	0.3910	0.0203
20	430.9963	425.4990	-425.1034	-511.1048	217382.438
21	0.0001	8.1117	0.0000	2645.0772	1021.729
22	66.3932	23.9660	23.8281	-30.1507	-0.0349
23	21.7571	21.7536	0.4761	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	134.0796				
28	2019.9888	38291.3052	0.2782	61.0687	170.5572
29	3576.2477	21623.9744	31.7709	259814508.0	-154.1798
30	1107.4533	2009.8029	22747.4192	36.0614	7.7284
31	-9.1817	120.9129			
			ENGINE CUTOFF COMMAND		
1	580.4790	82591.187	102196.117	713601.508	5107521.188
2	22310.9194	20980.6321	21670099.50	20914410.25	13.9936
3	5228435.500	0.000	5995985.938	0.000	5230563.625
4	72150.229	0.000	-134394.703	0.000	106.3402
5	122329.577	0.000	-199689.453	0.000	0.7904
6	20665.3743	0.0000	21911.2417	0.0000	70.9532
7	-3560.4680	0.0000	-4684.7968	0.0000	-0.3821
8	672.5471	0.0000	-268.2490	0.0000	-0.9256
9	182137.973	182137.979	-0.004	-9.661	-0.045
10	-980.881	-980.885	0.057	556.110	0.011
11	-2379.920	-2379.979	-0.001	-963.174	1.007
12	9.9727	0.0055	-0.0040	105701.156	0.0809
13	-0.5102	-0.0030	0.0474	3158797.188	-0.2963
14	-0.0000	0.0000	0.0000	3158727.563	0.0000
15	-79.9670	0.0000	0.0000	0.0000	810.7173
16	-0.8065	0.0000	0.0000	0.0055	-3.8912
17	0.0000	0.0000	0.0000	-0.0030	-9.3378
18	4.2151	3.9633	4.0144	-0.7473	-0.0160
19	113.3607	111.8858	111.8770	0.3098	0.0240
20	431.6469	425.6036	-421.9606	-509.2761	216653.211
21	0.0001	8.2693	0.0000	2678.7257	1021.223
22	65.0072	23.7018	23.6448	-30.1163	-0.0337
23	21.8354	21.8334	0.3304	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	134.3710				
28	2176.2193	36403.1021	0.2440	64.6706	167.3991
29	3587.3153	22043.7317	31.7795	271860560.0	-150.6309
30	1296.5593	9212.0940	23269.7397	30.3826	4.0141
31	-8.6768	121.5514			

TABLE AP 6-2 (Sheet 1 of 12)
PROGRAMS AC77 AND AA83 SYMBOL DEFINITIONS

PRINTOUT SYMBOL	COMMON SYMBOL	DEFINITION
A*	A*	Azimuth angle measured in the plane tangent to the earth's surface at radar station, positive clockwise from north to the perpendicular projection of the vector drawn between the vehicle and the radar in the tangent plane (deg)
A SB XM A SB YM A SB ZM	a_{xm}, a_{ym}, a_{zm}	Vehicle accelerations in the vehicle coordinate system (ft/sec^2)
CHORD FORCE	C	Aerodynamic chord force (lbf)
D*	D*	Slant range distance between the vehicle and radar station (ft)
ECCENTRICITY	e	Eccentricity of a conic section (dimensionless)
E*	E*	Elevation angle measured positively up from a plane tangent to the earth's surface at the radar site. Angle between the plane and the vector drawn between the missile and radar station (ft)
E/M	E_m	Total energy (ft^2/sec^2)
F SB AUX SB X F SB AUX SB Y F SB AUX SB Z	F_{aux_x} F_{aux_y} F_{aux_z}	Auxiliary forces in the vehicle coordinate system (lbf)
F SB AX F SB AY F SB AZ	F_{A_x}, F_{A_y}, F_{A_z}	Aerodynamic forces in the vehicle coordinate system (lbf)

TABLE AP 6-2 (Sheet 2 of 12)
PROGRAMS AC77 AND AA83 SYMBOL DEFINITIONS

PRINTOUT SYMBOL	COMMON SYMBOL	DEFINITION
AVG F SB L	$\bar{F}_L$	Average longitudinal thrust (lbf)
F SB T	F_T	Total effective engine thrust (lbf)
F SB TX F SB TY F SB TZ	F_{T_x}, F_{T_y}, F_{T_z}	Propulsive forces in the vehicle system (lbf)
F SB X F SB Y F SB Z	F_x, F_y, F_z	Total forces in the vehicle coordinate system (lbf)
G (RHO)	g_ρ	Component of gravity due to the attractive force of the earth measured along r_c positive down (ft/sec^2)
G (PSI)	g_ψ	Component of gravity due to attractive force of the earth measured along the perpendicular to r_c positive down (ft/sec^2)
ALTITUDE	h	Vehicle altitude. Distance between the spheroid's surface and vehicle measured along the normal to the earth's surface positive up (ft)
INCLINATION	i	Equatorial orbital inclination (deg)
I SB SP	I_{sp}	Specific impulse (sec)
AVG I SB SP	$\bar{I}_{sp}$	Average specific impulse (sec)
I SB XX I SB YY I SB ZZ	I_{xx}, I_{yy}, I_{zz}	Principal vehicle moments of inertia ($slug\text{-}ft^2$)

TABLE AP 6-2 (Sheet 3 of 12)
PROGRAMS AC77 AND AA83 SYMBOL DEFINITIONS

PRINTOUT SYMBOL	COMMON SYMBOL	DEFINITION
MACH NO.	M	Vehicle mach number
M SB X M SB Y M SB Z	M_x, M_y, M_z	Total moments about the axis of the vehicle coordinate system (ft-lbf)
M SB AX M SB AY M SB AZ	M_{A_X}, M_{A_Y}, M_{A_Z}	Aerodynamic moments in the vehicle coordinate system (ft-lbf)
NORMAL FORCE	N	Aerodynamic normal force (lbf)
PERIOD	P	Period of elliptical orbit (min)
P SB M	P_M	Total vehicle roll rate; positive roll clockwise looking forward along the X_m axis (deg/sec)
PRESSURE	P_a	Atmospheric pressure at the vehicle (lbf/ft^2)
Q	q	Vehicle dynamic pressure (lbf/ft^2)
Q SB M	Q_M	Total vehicle pitch rate, positive nose up (deg/sec)
R (AP)	r_a	Radius of apogee (nautical miles)
R (PER)	r_{PER}	Radius of perigee (nautical miles)
R SB C	r_c	Instantaneous distance between the center of the earth and the vehicle (ft)
R SB L	r_L	Earth radius at the launcher (ft)
R SB M	R_M	Total vehicle yaw rate; positive yaw-nose left (deg/sec)

TABLE AP 6-2 (Sheet 4 of 12)
PROGRAMS AC77 AND AA83 SYMBOL DEFINITIONS

PRINTOUT SYMBOL	COMMON SYMBOL	DEFINITION
S (BAR*)	$\bar{S}^*$	Product of the average earth radius and the central angle traversed during glide (nautical miles)
S SB F	S_F	Downrange distance at terminal altitude (nautical miles)
RANGE	s	Spherical earth ground range (ft). Based on the spherical earth range angle and the average earth radius
SAF	SAF	Space attenuation factor measured from radar station i
TIME	t	Current simulation time, measured from vehicle liftoff (sec)
T SB F	t_f	Time since launch at the terminal altitude (sec)
T (1)	T_1	First stage time to go (sec)
T (3)	T_3	Second stage time to go (sec)
DELTA-T (3)	ΔT_3	Correction to T_3 (sec)
D-T (CO)	Δt_{co}	Time-to-go until engine cutoff command (sec)
TEMPERATURE	T_R	The temperature specified at a certain altitude (deg R)
V (AP)	V_{ap}	Apogee velocity of the glide phase orbit (ft/sec)
V SB E	V_e	Magnitude of the vehicle's earth fixed velocity (ft/sec)

TABLE AP 6-2 (Sheet 5 of 12)
PROGRAMS AC77 AND AA83 SYMBOL DEFINITIONS

PRINTOUT SYMBOL	COMMON SYMBOL	DEFINITION
V (F)	V_f	Magnitude of inertial velocity at terminal altitude (ft/sec)
V SB I	V_I	Magnitude of the vehicle's inertial velocity (ft/sec)
V (PER)	V_{per}	Perigee velocity of the glide phase orbit (ft/sec)
V SB RM	V_{RM}	Magnitude of the vehicle's velocity relative to the earth's atmosphere (ft/sec)
V SB W	V_W	Wind velocity relative to the earth (ft/sec)
WEIGHT	W	Total vehicle weight (lbf)
WEIGHT FLOW	$\dot{W}$	Time rate of change of total vehicle weight (lbm/sec)
AVG D-W	$\bar{\dot{W}}$	Average time rate of change of total vehicle weight (lbm/sec)
X, Y, Z	X, Y, Z	Components of vehicle position, velocity, and accelerations. A subscript on these quantities indicates the coordinate system in which these quantities are measured. (ft, ft/sec, ft/sec^2, respectively)
X SB CG Y SB CG Z SB CG	X_{CG}, Y_{CG}, Z_{CG}	Components of vehicle center of gravity, with X_{CG} measured positive forward from the vehicle reference plane, Y_{CG} measured positive right from the missile centerline, and Z_{CG} measured positive down from the vehicle centerline (in.)

TABLE AP 6-2 (Sheet 6 of 12)
PROGRAMS AC77 AND AA83 SYMBOL DEFINITIONS

PRINTOUT SYMBOL	COMMON SYMBOL	DEFINITION
X SB CP	X_{CP}, Y_{CP}, Z_{CP}	Components of vehicle center of pressure with X_{CP} measured positive forward from the vehicle reference plane. Y_{CP} measured positive right from the missile centerline, and Z_{CP} measured positive down from the vehicle centerline (in.)
X (V) Y (V) Z (V)	X^V, Y^V, Z^V	Position coordinates in the terminal radius coordinate system. Origin is at the earth's center, Y^V along the desired terminal radius, X^V in the orbit plane in the direction of orbital motion, Z^V forming a right handed coordinate system (m)
D-X (V) D-Y (V) D-Z (V)	X^V, Y^V, Z^V	Velocity coordinates in terminal radius coordinate system (m/sec)
ALPHA* (S-IVB)	α	Total angle of attack. Angle between the centerline of the vehicle and the vehicle air velocity vector (deg)
ALPHA (S-IVB)	α_P	Pitch angle of attack. Angle between the projection of the vehicle's air velocity vector onto the pitch plane and the centerline of the vehicle (deg)
BETA (S-IVB)	α_y	Yaw angle of attack. Angle between the projection of the vehicle's air velocity vector into the yaw plane and the centerline of the vehicle (deg)
ALPHA SB WP	α_{wp}	Wind angle of attack in pitch (deg)
ALPHA SB WY]	α_{wy}	Wind angle of attack in yaw (deg)

TABLE AP 6-2 (Sheet 7 of 12)
PROGRAMS AC77 AND AA83 SYMBOL DEFINITIONS

PRINTOUT SYMBOL	COMMON SYMBOL	DEFINITION
BETA	β	True anomaly at start of glide (deg)
BETA (F)	β_f	True anomaly at terminal altitude (deg)
GAMMA (1)	γ_1	Elevation flight path angle. Angle between the earth fixed vehicle velocity and the local tangent plane positive for an ascending vehicle (deg)
GAMMA (2)	γ_2	Azimuthal flight path angle. Angle between the local north clockwise to the projection of the earth fixed vehicle velocity on the local tangent plane (deg)
GAMMA (1I)	γ_{1_I}	Inertial elevation flight path angle. Same as γ_1 except measured to inertial vehicle velocity (deg)
GAMMA (2I)	γ_{2_I}	Inertial azimuthal flight path angle. Same as γ_2 except measured to inertial vehicle velocity (deg)
GAMMA (1I) PR	γ_{1_I}'	Inertial elevation flight path angle. Angle between the inertial velocity vector and the X_{L_I}' Z_{L_I}' plane. Angle is positive for an ascending vehicle (deg)
GAMMA (2I) PR	γ_{2_I}'	Inertial azimuthal flight path angle measured in the X_{L_I}' Z_{L_I}' plane. Angle between Z_{LI}, clockwise to the projection of the inertial velocity vector (deg)
GAMMA SB 1F	γ_{1_f}	Inertial flight path elevation angle at the terminal altitude (deg)

TABLE AP 6-2 (Sheet 8 of 12)
PROGRAMS AC77 AND AA83 SYMBOL DEFINITIONS

PRINTOUT SYMBOL	COMMON SYMBOL	DEFINITION
GAMMA SB 2F	γ_{2_f}	Inertial flight path azimuth angle, at the terminal altitude (deg)
DELTA (A) DELTA (B)	δ_A, δ_B	Vehicle actuator A (yaw) and actuator B (pitch)
D-DELTA (A)	$\dot{\delta}_A$, $\dot{\delta}_B$	Vehicle actuator A (yaw) and actuator B (pitch) gimbal angle rates, respectively (deg/sec)
SMCP	δMCP	Pitch thrust misalignment correction (radians)
SMCY	δMCY	Yaw thrust misalignment correction (radians)
E SB W	ϵ_W	Tabular wind azimuth angle, positive clockwise from north, as a function of altitude (at ϵ_W = zero, wind is coming from the north) (deg)
EPS (THETA) EPS (PSI) EPS (PHI)	ϵ_θ, ϵ_θ, ϵ_ϕ	Autopilot error signal (deg)
RANGE ANGLE	η'	Spherical earth range angle. The angle is measured between lines connecting the following three points: the vehicle, the center of the earth, and the launcher with the earth's center as the vertex (radians)
D-THETA (M) QRP D-PSI (M) QRP D-PHI (M) QRP	$\dot{\theta}_M$, $\dot{\psi}_M$, $\dot{\phi}_M$	Vehicle pitch, yaw, and roll attitude Euler angle rates (deg/sec)

TABLE AP 6-2 (Sheet 9 of 12)
PROGRAMS AC77 AND AA83 SYMBOL DEFINITIONS

PRINTOUT SYMBOL	COMMON SYMBOL	DEFINITION
THETA SB C	θ_C	Commanded vehicle pitch Euler angle (deg)
D-THETA SB C	$\dot{\theta}_C$	Commanded vehicle pitch Euler rate (deg/sec)
THETA (M) QRP PSI (M) QRP PHI (M) QRP	θ_M, μ_M, θ_M	Vehicle pitch, yaw, and roll attitude Euler angle (deg)
THETA (P) THETA (Y) THETA (R)	θ_P, θ_Y, θ_R	For the three-gimbal stable platform, pitch, yaw and roll angles, respectively (deg)
MU	μ	Instantaneous vehicle longitude where Greenwich, England, is longitude zero. West of Greenwich is positive (deg)
MU SB F	μ_f	Longitude of r_f (deg)
XI ETA ZETA	ξ, η, ζ	Vehicle position obtained by integrating $\dot{\xi}$, $\dot{\eta}$, $\dot{\zeta}$. The $\xi\eta\zeta$ system coincides with the P system at t = 0, and is falling with an acceleration equal to gravity at the vehicle position. Position and velocity in this system correspond to the position and velocity the vehicle would have if gravity were zero. (m)
D-XI D-ETA D-ZETA	$\dot{\xi}$, $\dot{\eta}$, $\dot{\zeta}$	Vehicle velocity obtained by integrating $\ddot{\xi}$, $\ddot{\eta}$, $\ddot{\zeta}$ (m/sec)
RHO	ρ	Instantaneous geodetic latitude, positive in the northern hemisphere (deg)
RHO PRIME	ρ'	Instantaneous geocentric latitude, positive in the northern hemisphere (deg)

TABLE AP 6-2 (Sheet 10 of 12)
PROGRAMS AC77 AND AA83 SYMBOL DEFINITIONS

PRINTOUT SYMBOL	COMMON SYMBOL	DEFINITION
RHO SB F	ρ_f	Longitude of r_f (deg)
TAU-P	T_p	Radar polarization look angle for the radar station: angle between the projection of the vehicle centerline on a plane perpendicular to the radar line of sight and the line of intersection of the plane containing the radar line of sight, perpendicular to the earth's surface, and the plane perpendicular to the radar line of sight, measured positive counterclockwise from this line of intersection as viewed looking along the radar line of sight toward the vehicle (deg).
TAU (1G)	τ_{1G}	Ratio of W/$\dot{W}$ during first stage operation (sec)
TAU (3G)	τ_{3G}	Ratio of W/$\dot{W}$ during third stage operation (sec)
TAU SB F	τ_f	Time since/to perigee at terminal altitude (sec)
PHI SB C	ϕ_C	Commanded vehicle roll Euler angle (deg)
D-PHI (T)	$\dot{\phi}_C$	Commanded vehicle roll Euler rate (deg/sec)
PHI (T)	ϕ_T	Estimate of terminal range angle measured in the orbit plane from the descending node to the terminal radius vector, positive in the flight direction (radians)

TABLE AP 6-2 (Sheet 11 of 12)
PROGRAMS AC77 AND AA83 SYMBOL DEFINITIONS

PRINTOUT SYMBOL	COMMON SYMBOL	DEFINITION
PSI SB C	Ψ_C	Commanded vehicle yaw Euler angle (deg)
D-PSI SB C	Ψ_C	Commanded vehicle yaw Euler rate (deg/sec)
CHI SB P CHI SB R CHI SB Y	X_P, X_R, X_Y	Guidance-commanded body attitude angle in the vehicle pitch, roll, and yaw plane (deg)
D-CHI SB P D-CHI SB R D-CHI SB Y	$\dot{X}_P$, $\dot{X}_R$, $\dot{X}_Y$	Guidance-commanded body attitude rates in the vehicle pitch, roll, and yaw plane (deg/sec)

LIST OF COORDINATE SUBSCRIPT DEFINITIONS

ee — Coordinate system on the surface of the spheroid representing the earth and whose origin is at the same latitude and longitude as the launcher. X_{ee} positive downrange, Y_{ee} perpendicular to the surface of the spheroid, positive up, and Z_{ee} crossrange positive in the right handed coordinate system. (English)

LL — Instantaneous coordinate system located on the earth's surface under the vehicle with the X_{LL}, Z_{LL} plane tangent to the earth's surface. Positive directions are X_{LL} west, Y_{LL} up, and Z_{LL} north. (English)

L_I — Instantaneous inertial coordinate system coincidental with the L system. Velocities in this system are inertial. (English)

L'_I — Instantaneous inertial coordinate system located on the earth's surface under the vehicle where Z_L' points north, X_L' points west and Y_L' is along a line connecting the earth center and the vehicle. Velocities in this system are inertial. (English)

TABLE AP 6-2 (Sheet 12 of 12)
PROGRAMS AC77 AND AA83 SYMBOL DEFINITIONS

m	Vehicle coordinates fixed at the center of gravity of the vehicle. X_m parallel to the longitudinal axis of the vehicle positive forward, Y_m at the zero deg bank angle position, and A_m at the 90 deg bank angle position. (English)
P'	Inertial coordinate system with its origin at the center of the earth and with its X_p axis along the line parallel to the local gravity vector at launch through the earth's center, positive up. The X_p axis is parallel to the plane defined by the X_x and Y_x axis at launch and Z_p forms a right-handed coordinate system. (Metric)
s	Coordinates initially coincident with the e system, but remaining fixed in space. (English)
SFE	Space Fixed Ephermeris System. The origin of the system is at the center of the earth, Z_{SFE} is positive north, X_{SFE} passes through the vernal equinox and Y_{SFE} completes the right handed system with the X_{SFE} $-Y_{SFE}$ plane coincident with the equatorial plane. The directions of the axes remain fixed in space and the origin moves with the center of the earth. The reference equinox and equator are the true vernal equinox and equator for the epoch of midnight of the day of the launch. (English)
PLI	Coordinates initially oriented with the "ee" system, but orientation remains fixed in space. Used to measure inertial platform position and velocities.
G	Same orientation as "S" system used to measure components of gravitational position vector
SP	Space fixed ephermeris coordinate system. In AA83 equivalent to SFE coordinate system.

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P. 464

1. OBSERVED TRAJECTORY

This appendix presents a detailed tabulation of the observed trajectory from range zero (0 sec) to spacecraft separation (RO +600.0 sec). The trajectory data are obtained from radar tracking histories and the aerodynamic data are based on the final meteorological summary of appendix 8.

The trajectory contains a three-sigma deviation of 740 ft in slant range and 3.3 ft in earth-fixed velocity.

Table AP 6-2 presents the definition of symbols for the trajectory parameters contained in table AP 7-1. The last three rows in table AP 7-1 contain the vehicle radar parameters for the following radar sites:

1. Launch Pad 34,
2. TEL 2 (KSC),
3. Grand Bahama Island,
4. Bermuda,
5. Antigua.

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TABLE AP 7-1 (Sheet 1 of 10)
OBSERVED TRAJECTORY TABULATION

			RANGE ZERO		
1	TIME	X SUB EE	Y SUB EE	Z SUB EE	D-X SUB EE
2	D-Y SUB EE	D-Z SUB EE	D-DX SUB EE	D-DY SUB EE	D-DZ SUB EE
3	ALTITUDE	RANGE	V SUB E	V SUB I	GAMMA SUB I
4	GAMMA SUB 2	GAMMA SB 1E*	GAMMASB 2I*	PU	RHO
5	SIGMA EE	SIGMA YEE	SIGMA ZEE	SIGMA DYEE	SIGMA DZEE
6	SIGMA DZEE	SIGMA DDYEE	SIGMA DDYEE	SIGMA DDZEE	V SB R
7	ALPHA SB AP	ALPHA SB AY	RE/L	U	MACH
8	DENSITY	A SB KM	XPLE	YPLE	ZPLE
9	DXPLE	DYPLE	DZPLE		
10	XS	YS	ZS	DXS	DYS
11	DZS	XG	YG	ZG	DXG
12	DYG	DZG	XSP	YSP	ZSP
13	DXSP	DYSP	DZSP		
14	TEMPERATURE	PRESSURE	WIND SPEED	WIND AZIMUTH	
15	U STAR SUB 1	A STAR SUB 1	F STAR SUB 1	D STAR SUB 2	A STAR SUB 2
16	E STAR SUB 2	D STAR SUB 3	A STAR SUB 3	E STAR SUB 1	D STAR SUB 4
17	A STAR SUB 4	E STAR SUB 4	D STAR SUB 5	A STAR SUB 5	E STAR SUB 5

1	0.0000	0.0	105.0	0.0	0.000
2	0.000	0.000	0.000	0.000	0.000
3	109.4214	0.2953	0.0000	1341.76312	-0.0000
4	0.0300	-0.0000	90.0000	80.56114	28.5220
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	14.707
7	-90.0000	-67.6010	0.0367	0.3125	0.0145
8	0.0022393	32.1126	0.014	97.813	-0.012
9	0.0080	43.7505	-0.0021		
10	5790.6	-0.6	-1552.1	1295.991	-0.384
11	-141.476	-0.150	-321.523	-0.443	-0.074
12	-143.922	-0.196	-16222625.000	8682972.3	9932699.1
13	-633.171	-1182.973	0.000		
14	544.8001	2115.8580	16.824	172.432	
15	104.5	360.00000	89.87114	5654.3	59.11613
16	0.33422	1005212.0	313.73172	-1.37282	5183738.3
17	258.63869	-7.10950	7501291.2	306.58406	-10.34265

1	5.0000	0.1	177.2	-0.9	-0.039
2	34.502	-0.624	-0.041	8.548	-0.250
3	176.6447	1.3793	34.5077	1342.33598	88.9619
4	11.5001	1.4728	89.9697	80.56114	28.5220
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	14.133
7	-90.0497	-202.5330	0.0938	1.6255	0.0332
8	0.0027357	40.674	0.133	460.939	-0.306
9	0.0250	103.2263	-0.1999		
10	12270.5	68.5	-3290.9	1295.917	33.698
11	-348.332	-0.825	-1443.781	-1.949	-0.204
12	-304.941	-0.404	-16225845.000	8677087.1	9932734.6
13	-659.277	-1169.160	17.013		
14	544.4357	2110.8038	17.111	174.104	
15	176.7	17.47092	89.65636	5655.9	59.10996
16	1.06260	1005214.0	313.73177	-1.36871	5183746.7
17	258.63870	-7.10871	7501304.2	306.58407	-10.34210

1	10.0000	-0.9	461.7	-7.3	-0.419
2	80.148	-1.977	-0.084	9.722	-0.283
3	460.9424	8.6743	80.3730	1344.29791	88.5593
4	3.0484	3.4263	89.9042	80.56114	28.5220
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	81.474
7	-2.9923	-189.5046	0.2450	7.4454	0.0713
8	0.0022214	41.847	0.161	1133.518	-2.361
9	-0.0139	166.1588	-0.6275		
10	16749.3	347.6	-5036.5	1295.544	79.104
11	-349.929	-2.274	-3371.326	-4.457	-0.384
12	-466.037	-0.597	-16229226.125	8671285.6	9932876.0
13	-693.787	-1150.735	40.139		
14	542.9992	2090.8739	18.251	180.697	
15	461.0	8.12473	89.07027	5672.3	59.05824
16	3.93434	1005224.7	313.73207	-1.35252	5183779.1
17	258.63876	-7.10559	7501357.6	306.58411	-10.33997

1	15.0000	-3.3	988.7	-20.9	-0.438
2	131.467	-3.541	0.130	10.776	-0.155
3	987.8975	23.9656	131.5157	1348.73941	88.4454
4	7.9445	5.5933	89.8334	80.56113	28.5220
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000300	0.0000000	0.0000000	0.0000000	132.418
7	-3.1808	-351.4062	0.5267	19.2368	0.1157
8	0.0021942	42.901	0.101	2124.916	-0.687
9	0.0473	230.6987	-1.1277		
10	25226.9	867.4	-6790.5	1295.580	129.793
11	-351.750	-4.747	-6104.136	-7.901	-0.614
12	-627.086	-0.778	-16232789.250	8665582.5	9933139.8
13	-732.549	-1130.546	65.880		
14	540.4151	2053.9579	20.158	195.560	
15	988.2	6.14417	88.76552	5740.8	58.94523
16	9.18184	1005246.2	313.73269	-1.32250	5183939.6
17	258.63890	-7.09980	7501457.8	306.58422	-10.33602

1	20.0000	-1.8	1786.5	-43.9	1.436
2	149.029	-5.564	0.670	12.332	-0.449
3	1785.7282	48.4283	189.1159	1357.92644	88.7588
4	29.4675	8.0011	89.7642	80.56111	28.5221
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0003000	0.0000000	0.0000000	0.0000000	189.885
7	-3.2747	-176.8705	0.9544	38.7656	0.1065
8	0.0021503	44.460	1.732	3443.821	-11.885
9	0.7383	297.1938	-1.7773		
10	31708.7	1655.8	-8554.8	1297.567	186.970
11	-354.048	-8.493	-9642.169	-12.212	-0.893
12	-788.126	-0.965	-16236561.250	8659981.4	9933939.5
13	-777.264	-1109.446	94.656		
14	536.8004	1998.0795	24.135	221.178	
15	1786.4	12.51772	88.59725	5937.6	58.79713
16	16.77921	1005275.8	313.73388	-1.27705	5183923.8
17	258.63910	-7.09104	7501605.1	306.58440	-10.33003

1	25.0000	16.9	2892.8	-77.1	6.732
2	254.534	-7.933	1.496	13.900	-0.491
3	2891.9940	86.2585	255.0465	1374.34078	87.6621
4	55.3229	10.6850	89.7185	80.56103	28.5222
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	255.524
7	2.9524	-177.6973	1.5481	68.0870	0.2249
8	0.0020856	46.044	9.308	5101.051	-24.654
9	2.5081	366.1984	-2.5435		
10	38208.5	2750.4	-10331.6	1303.045	252.282
11	-356.715	-13.762	-13985.363	-17.323	-1.223
12	-949.150	-1.098	-16240575.750	8654489.1	9934092.1
13	-830.225	-1087.863	126.884		
14	532.8511	1922.7795	29.528	221.473	
15	2893.2	27.28471	88.43267	6379.5	58.69912
16	26.23687	1005304.0	313.73608	-1.21403	5184027.0
17	258.63929	-7.07885	7501794.3	306.58469	-10.32171

1	30.0000	73.7	4364.7	-173.2	17.047
2	326.928	-10.538	2.749	15.106	-0.587
3	4343.9696	152.2666	327.5412	1399.94451	86.4923
4	73.2799	13.5042	89.7106	80.56092	28.5222
5	0.0000300	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	327.427
7	3.8392	-178.8154	2.1262	107.4559	0.2498
8	0.0020037	47.302	29.366	7108.554	-39.441
9	5.8454	437.1021	-5.1949		
10	44747.4	4188.4	-12122.4	1313.615	321.914
11	-359.648	-20.803	-19133.627	-23.165	-1.402
12	-1110.155	-1.237	-16244875.500	8649100.0	9934611.5
13	-890.843	-1067.835	161.173		
14	527.4129	1827.2830	36.049	230.325	
15	4366.4	45.65538	88.10625	7199.7	58.79125
16	36.39744	1005315.2	313.73992	-1.11176	5184135.5
17	258.63935	-7.06784	7502012.1	306.58516	-10.31076

1	35.0000	201.0	6173.0	-185.0	35.539
2	405.526	-14.444	4.691	16.526	-0.647
3	6172.3648	281.5744	407.3365	1414.55797	84.5968
4	82.8819	16.3729	89.7554	80.56019	28.5221
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	485.949
7	3.7985	-4.6872	3.3112	156.4919	0.3618
8	0.0019038	48.867	71.969	9475.474	-52.370
9	11.7144	509.9771	-4.6592		
10	51358.3	6000.7	-13930.6	1332.440	402.019
11	-363.921	-29.868	-25086.058	-29.670	-2.032
12	-1151.134	-1.363	-16249499.375	8643803.4	9935708.0
13	-960.759	-1052.267	197.814		
14	521.0491	1712.3313	42.823	234.053	
15	6178.4	62.36093	87.46595	8506.7	59.26437
16	45.81941	1005384.8	313.74642	-1.02696	5184224.9
17	258.63910	-7.04259	7502234.9	306.58588	-10.29665

1	40.0000	443.9	8413.2	-268.6	61.981
2	491.630	-19.215	6.425	17.917	-1.990
3	8412.5206	525.6926	496.0314	1491.54685	82.3416
4	68.0626	19.2450	89.8531	80.55959	28.5224
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	493.509
7	-2.5978	-4.1927	4.5164	211.2703	0.4411
8	0.0017841	50.439	131.084	12212.284	-86.414
9	20.3868	585.1143	-6.2066		
10	58086.7	8221.6	-15762.8	1360.411	487.584
11	-369.110	-41.210	-31844.905	-36.767	-2.511
12	-1432.082	-1.474	-16254501.500	8638570.6	9936703.9
13	-1041.360	-1041.206	236.714		
14	513.3669	1579.4329	42.651	227.000	
15	8428.6	73.80533	86.47074	10368.7	60.14079
16	53.55412	1005178.9	313.75710	-0.89903	5184259.4
17	258.63833	-7.01768	7502427.4	306.58699	-10.27975

1	45.0000	849.1	11102.2	-376.4	100.934
2	585.089	-23.479	8.659	19.416	-0.644
3	11101.4921	933.6666	594.1982	1559.90312	79.9581
4	61.9094	25.1988	90.0716	80.55828	28.5226
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	590.404
7	2.0615	-3.5567	5.9631	286.2118	0.5345
8	0.0016416	52.254	281.206	15330.961	-121.257
9	32.2481	662.4634	-7.6223		
10	66980.0	10689.5	-17621.1	1398.793	580.444
11	-373.492	-55.089	-39097.599	-44.387	-3.047
12	-1592.992	-1.571	-16259933.125	8633367.4	9938078.9
13	-1133.620	-1035.296	276.350		
14	506.6292	1431.3943	42.651	225.464	
15	11140.4	81.08119	85.21735	12616.7	62.16771
16	59.38163	1004961.4	313.77310	-0.76524	5184205.7
17	258.63676	-6.98765	7502552.7	306.58859	-10.25903

1	50.0000	1473.5	14276.5	-507.1	151.514
2	685.408	-26.873	11.722	20.604	-0.739
3	14275.8896	1558.8541	702.4695	1645.52780	77.3507
4	96.9478	24.6173	90.4364	80.55631	28.5222
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	697.526
7	1.7794	-3.2880	7.6718	362.3394	0.6380
8	0.0014894	53.980	479.851	18840.675	-162.227
9	48.0371	741.8650	-8.8000		
10	72095.2	14036.5	-19499.9	1450.008	680.044
11	-377.798	-71.766	-47774.731	-52.457	-3.633
12	-1753.857	-1.654	-16265858.750	8628207.1	9939557.1
13	-1238.608	-1036.337	315.631		
14	496.9310	1271.7281	45.932	224.000	
15	14360.5	86.18143	83.77666	15870.5	64.45792
16	83.50634	1004583.9	313.79622	-0.96330	5184075.2
17	258.63397	-6.95204	7502562.3	306.59075	-10.23440

1	55.0000	2390.5	17986.6	-645.2	218.078
2	791.460	-30.171	14.968	21.604	-0.683
3	17966.2400	2474.5219	821.5090	1750.64424	74.4421
4	97.1298	26.8819	90.9207	80.55144	28.5220
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	815.104
7	1.5116	-3.0661	9.6586	440.3618	0.7545
8	0.0013249	55.918	769.849	22752.719	-209.369
9	68.7502	822.9643	-9.9812		
10	79506.4	17700.3	-21399.4	1517.322	785.346
11	-381.742	-91.516	-58946.053	-60.906	-4.278
12	-1914.668	-1.723	-16272342.875	8623000.5	9941232.0
13	-1357.049	-1047.813	353.932		
14	485.7320	1105.0580	49.213	222.095	
15	18135.7	89.89705	82.15300	19555.5	68.35696
16	66.20866	1003988.0	313.82784	-0.35127	5183663.3
17	258.62949	-6.91041	7502392.4	306.59360	-10.20950

1	60.0000	3660.6	22201.4	-799.6	300.731
2	902.871	-31.114	18.177	22.557	3.030
3	22200.8311	3760.0035	952.1464	1874.10299	71.4964
4	99.1021	28.8070	91.5795	80.54944	28.5215
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	947.911
7	0.6700	-2.0695	11.9393	519.7161	0.8905
8	0.0011568	57.560	1175.452	27073.354	-260.833
9	94.4226	905.6398	-10.4807		
10	87294.9	21902.1	-23313.4	1600.848	895.840
11	-383.435	-114.620	-66921.273	-69.661	-4.976
12	-2035.498	-1.777	-16279553.125	8617714.0	9943391.8
13	-1489.343	-1068.972	389.135		
14	471.5257	936.3284	36.313	213.932	
15	22518.0	92.73871	80.37119	23903.8	72.45255
16	67.77765	1003106.8	313.87001	-0.10703	5183062.5
17	258.62276	-6.86236	7501970.7	306.59725	-10.17202

TABLE AP 7-1 (Sheet 2 of 10)
OBSERVED TRAJECTORY TABULATION

1	65.0300	5425.0	26994.4	-936.7	399.575
2	1013.047	-32.133	21.196	21.475	-9.403
3	26994.1172	5495.5078	1089.4731	2012.51956	68.4262
4	105.4140	30.2317	92.2928	80.54407	28.5228
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	1065.933
7	0.4512	-7.2159	14.5215	582.7709	1.0389
8	0.0000983	57.566	1722.247	31809.107	-314.324
9	125.0279	987.8716	-11.0415		
10	93542.1	76657.2	-25234.2	1700.692	1004.950
11	-385.314	-141.317	-77100.074	-78.648	-5.737
12	-22300.099	-1.816	-16297750.375	8612789.5	9945117.1
13	-1629.714	-1103.706	420.130		
14	454.7292	771.2868	42.938	206.213	
15	27549.9	94.99679	78.46580	28942.4	76.79990
16	66.45764	1001472.7	313.92451	0.17067	5182164.6
17	256.61323	-6.80764	7501221.4	306.60179	-10.13372
1	70.0000	7704.9	32330.5	-1121.1	516.144
2	1122.015	-33.631	25.533	22.478	-9.203
3	32331.2332	7763.9996	1235.4916	2166.67212	65.2725
4	101.3501	31.2078	93.0374	80.53710	28.5195
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	1732.985
7	0.1964	-2.0552	17.3971	633.2540	1.2123
8	0.0004331	60.194	2435.013	36951.493	-321.393
9	161.1544	1069.6576	-11.7298		
10	104330.2	31949.8	-27167.0	1818.296	1112.674
11	-387.596	-172.100	-89282.092	-87.794	-6.563
12	-23366.701	-1.840	-16295764.750	8606653.5	9947286.3
13	-1776.966	-1153.128	446.755		
14	430.5732	815.5867	44.558	201.256	
15	33254.1	96.71922	76.45926	34684.7	80.99037
16	68.43268	1000224.9	333.99349	0.48162	5180900.6
17	256.60032	-6.74631	7500066.9	306.60741	-10.09062
1	75.0000	10676.1	38227.7	-1290.4	654.869
2	1237.579	-34.169	30.767	23.731	-9.104
3	38229.7158	10676.0315	1401.5161	2345.01596	62.0393
4	102.0418	31.8740	93.8473	80.52820	28.5178
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	1386.134
7	1.1484	-1.6916	20.9760	650.3973	1.4017
8	0.0006770	65.6876	3340.269	42508.447	-431.533
9	204.7154	1153.3573	-12.3028		
10	113765.1	37796.5	-29109.9	1960.219	1226.763
11	-389.486	-267.123	-101666.906	-97.024	-7.459
12	-25557.217	-1.850	-16305072.500	8630729.3	9949581.4
13	-1946.904	-1219.399	470.561		
14	467.1318	872.9493	52.493	233.221	
15	39697.3	98.01551	76.35998	41190.0	84.90662
16	67.86014	998090.2	314.08104	0.82773	5179189.9
17	256.58343	-6.67802	7498410.3	306.61429	-10.04242
		79.5	MAXIMUM DYNAMIC PRESSURE		
1	79.5000	13906.7	44042.4	-1445.0	803.943
2	1347.645	-37.850	34.340	25.412	9.869
3	44044.6537	13933.0438	1569.5701	2525.93384	59.1187
4	102.6866	32.2713	94.6381	80.51824	28.5159
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	1563.997
7	0.3227	-0.6878	23.7109	669.3211	1.6326
8	0.0005473	66.904	4367.879	47871.445	-487.335
9	250.1761	1230.4417	-12.2658		
10	127911.5	43559.3	-30864.0	2108.500	1335.282
11	-389.340	-267.616	-111649.250	-105.143	-8.327
12	-27701.601	-1.846	-16314205.375	8595083.3	9951741.4
13	-2114.852	-1291.924	488.551		
14	382.0497	358.7746	21.637	227.866	
15	46707.7	99.07490	72.38757	47771.8	87.61812
16	66.97829	995644.7	314.17749	1.17186	5177191.8
17	256.56412	-6.61018	7496197.6	306.62174	-9.99431
1	80.0000	14161.0	44719.5	-1459.3	821.253
2	1360.192	-32.459	34.742	25.633	9.840
3	44721.5635	14337.0038	1589.3846	2547.09122	58.9011
4	102.7617	32.3110	94.7101	80.51701	28.5157
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	1562.870
7	0.3705	-0.7419	24.0760	666.7642	1.6568
8	0.0005122	67.298	4494.304	48488.825	-493.444
9	255.5202	12394.1591	-12.1901		
10	129972.1	44230.0	-31058.6	2125.932	1347.845
11	-389.111	-266.804	-114434.057	-106.286	-8.427
12	-27717.634	-1.844	-16315268.000	8594435.0	9951986.0
13	-2134.504	-1300.426	490.374		
14	380.0194	347.0368	24.882	223.224	
15	46976.2	99.17407	72.16569	48549.0	88.15169
16	66.88149	995341.5	314.18933	1.21216	5178940.7
17	256.56170	-6.60274	7498139.9	306.62264	-9.98867
1	85.0000	14813.0	44719.5	-1459.3	821.253
2	1360.192	-32.459	34.742	25.633	9.840
3	44721.5635	14337.0038	1589.3846	2547.09122	58.9011
4	102.7617	32.3110	94.7101	80.51701	28.5157
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	1562.870
7	0.3705	-0.7419	24.0760	666.7642	1.6568
8	0.0005122	67.298	4494.304	48488.825	-493.444
9	255.5202	12394.1591	-12.1901		
10	129972.1	44230.0	-31058.6	2125.932	1347.845
11	-389.111	-266.804	-114434.057	-106.286	-8.427
12	-27717.634	-1.844	-16315268.000	8594435.0	9951986.0
13	-2134.504	-1300.426	490.374		
14	380.0194	347.0368	24.882	223.224	
15	46976.2	99.17407	72.16569	48549.0	88.15169
16	66.88149	995341.5	314.18933	1.21216	5178940.7
17	256.56170	-6.60274	7498139.9	306.62264	-9.98867
1	85.0000	14813.0	44719.5	-1459.3	821.253
2	1360.192	-32.459	34.742	25.633	9.840
3	44721.5635	14337.0038	1589.3846	2547.09122	58.9011
4	102.7617	32.3110	94.7101	80.51701	28.5157
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	1562.870
7	0.3705	-0.7419	24.0760	666.7642	1.6568
8	0.0005122	67.298	4494.304	48488.825	-493.444
9	255.5202	12394.1591	-12.1901		
10	129972.1	44230.0	-31058.6	2125.932	1347.845
11	-389.111	-266.804	-114434.057	-106.286	-8.427
12	-27717.634	-1.844	-16315268.000	8594435.0	9951986.0
13	-2134.504	-1300.426	490.374		
14	380.0194	347.0368	24.882	223.224	
15	46976.2	99.17407	72.16569	48549.0	88.15169
16	66.88149	995341.5	314.18933	1.21216	5178940.7
17	256.56170	-6.60274	7498139.9	306.62264	-9.98867
1	90.0000	15485.8	51448.5	-1617.5	1009.072
2	1491.540	-31.954	40.701	26.653	0.057
3	51456.4031	14873.1086	1801.1199	2775.80755	55.9598
4	101.2906	32.5678	95.5661	80.50321	28.5128
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	1809.855
7	-0.1162	-0.5949	27.9199	674.6244	1.9171
8	0.0002931	71.182	5911.000	54404.443	-554.294
9	313.5510	13271.3939	-12.3901		
10	135062.1	51291.4	-33003.8	2315.279	1477.013
11	-389.741	-291.530	-128843.042	-115.444	-9.477
12	-28777.934	-1.824	-16326450.500	8587700.6	9954486.6
13	-2341.353	-1397.294	509.932		
14	359.4122	242.1894	19.845	168.109	
15	55753.4	100.10185	69.92787	56886.1	91.00188
16	65.56862	991925.9	314.32164	1.63827	5174377.9
17	256.53432	-6.51835	7493158.4	306.63259	-9.92890
1	95.0000	24451.9	59645.7	-1770.7	1225.168
2	1676.277	-29.355	45.564	28.621	0.524
3	57654.5836	24415.2274	2078.6689	3027.44231	53.0950
4	100.5769	32.5888	96.4061	80.48439	28.5093
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	2059.322
7	-0.7865	-0.2144	32.1260	535.8770	2.1589
8	0.0002527	75.333	7644.643	61765.812	-616.233
9	368.3400	14371.1680	-12.2717		
10	147171.1	59010.4	-34952.4	2553.260	1611.347
11	-389.376	-341.719	-163033.328	-124.485	-10.614
12	-30038.155	-1.790	-16338727.500	8580429.4	9957072.0
13	-2368.684	-1514.256	521.746		
14	378.8120	164.2428	36.089	116.950	
15	64487.1	100.85798	67.65590	66250.1	93.37070
16	64.04623	987737.1	314.48263	2.11131	5170494.5
17	256.50066	-6.42577	7489344.8	306.64444	-9.86266
1	95.0000	31172.9	68140.6	-1911.2	1468.100
2	1769.644	-28.012	51.540	28.541	-9.575
3	68163.2113	31092.5491	2299.3190	3304.24115	50.4305
4	100.9252	32.4253	97.1368	80.44615	28.5249
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	2325.424
7	-0.7991	-0.1979	36.7169	448.3369	2.4310
8	0.0001657	79.443	9729.687	69079.116	-677.835
9	455.2469	15049.2139	-12.7303		
10	160436.1	67413.9	-36899.7	2777.785	1749.978
11	-390.805	-397.829	-159924.305	-133.315	-11.446
12	-31988.731	-1.740	-16352168.125	8572526.4	9959720.9
13	-2813.799	-1651.137	535.593		
14	381.2755	108.3712	42.651	114.683	
15	74956.3	101.44750	65.37595	76021.3	95.32159
16	62.36924	982683.6	314.67649	2.63362	5166995.1
17	256.45921	-6.32397	7494581.3	306.65847	-9.78947
1	100.0000	39141.6	77352.5	-2057.1	1741.019
2	1915.793	-27.971	57.221	29.612	-9.993
3	77388.6504	39048.4434	2588.8289	3611.27929	47.8199
4	104.1406	32.1016	97.8705	80.44209	28.4996
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	2619.718
7	-0.7150	0.1837	41.6835	352.3402	2.6904
8	0.0000102	84.046	12212.715	76850.737	-761.275
9	539.4412	16005.5138	-13.2051		
10	175002.2	76519.6	-38859.3	3052.675	1892.925
11	-392.222	-460.158	-175635.326	-141.862	-13.181
12	-33581.170	-1.676	-16368892.125	8563880.4	9962420.0
13	-3079.620	-1810.705	542.582		
14	397.3277	70.0519	44.967	93.765	
15	86734.8	101.99449	63.10317	84706.7	96.20318
16	60.58440	976675.0	314.90907	3.21017	5160763.6
17	256.40973	-6.21246	7478739.9	306.67490	-9.70899
1	105.0000	46628.5	87306.7	-2195.7	2042.148
2	2065.940	-27.493	63.339	30.281	-9.046
3	87362.1133	46823.5039	2905.0159	3948.82373	45.4618
4	104.3031	31.6679	98.5184	80.41376	28.4932
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	2941.497
7	-0.7617	0.1862	47.0405	272.3625	2.9684
8	0.0000079	88.788	15138.094	85086.732	-810.438
9	632.3173	16931.0142	-13.8771		
10	191010.6	86350.3	-40829.5	3155.918	2039.499
11	-394.398	-529.852	-192805.682	-150.050	-14.634
12	-35517.962	-1.597	-16382993.125	8554384.9	9965142.5
13	-3263.691	-1991.363	545.411		
14	409.4300	44.1529	55.774	96.973	
15	99558.9	102.41451	60.85773	102040.1	98.19109
16	58.73796	969620.8	315.18574	3.84595	5154196.8
17	256.35099	-6.09070	7471690.8	306.69411	-9.62077
1	110.0000	59655.7	98018.5	-2132.2	2373.766
2	2219.257	-26.781	69.379	30.944	0.272
3	96102.7285	59362.4375	3249.7054	4108.44229	43.2140
4	104.4438	31.1137	99.1167	80.38074	28.4857
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	3291.415
7	-0.6791	0.0657	52.8516	205.6443	3.2773
8	0.0000380	93.632	18551.445	93791.566	-887.708
9	734.5737	17886.0471	-14.5813		
10	208612.4	96420.5	-42803.4	3649.467	2184.707
11	-396.615	-606.910	-210794.600	-157.604	-15.211
12	-36171.595	-1.503	-16400562.000	8543928.9	9967465.8
13	-3267.292	-2195.277	542.403		
14	419.9088	27.3518	57.061	101.000	
15	114768.2	102.76115	58.65505	116955.4	99.23858
16	56.86308	961438.6	315.51314	4.54598	5146843.4
17	256.28201	-5.95819	7463302.5	306.71619	-9.52638
1	115.0000	72487.3	109504.8	-2442.8	2734.179
2	2375.499	-25.461	75.668	31.607	3.311
3	109628.9248	72012.7412	3623.5785	4698.56195	41.1599
4	104.5752	30.5299	99.6706	80.34258	28.4770
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	3672.166
7	-0.6319	0.1353	59.0669	153.4368	3.6165
8	0.0000228	98.807	22499.586	102988.888	-956.643
9	846.3073	18882.8345	-15.2109		
10	227960.5	108242.5	-44791.6	4054.713	2393.287
11	-398.572	-692.191	-229381.227	-165.040	-17.929
12	-38837.057	-1.395	-16419699.125	8532393.8	9970559.3
13	-3990.303	-2422.639	533.672		
14	428.7568	16.7597	62.336	95.681	
15	131306.8	103.05204	56.50729	133597.3	100.09823
16	54.98868	952030.0	315.89948	5.31656	5138113.8
17	258.20171	-5.81442	7453438.1	306.74201	-9.41942
1	120.0000	87071.9	121781.4	-2546.1	3130.852
2	2535.520	-23.865	82.254	32.379	0.323
3	121960.7236	86526.9111	4028.8580	5119.70331	39.2184
4	104.6925	29.8841	100.1780	80.29881	28.4749
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	4090.018
7	-0.6927	0.1972	65.7168	110.7581	3.9961
8	0.0000132	104.413	27031.040	112672.150	-1034.321
9	967.9731	19788.5776	-15.8759		
10	249213.7	120310.5	-46789.5	4452.014	2695.060
11	-400.691	-786.413	-249166.709	-171.734	-19.790
12	-39986.918	-1.270	-16440500.875	8519862.5	9973193.9
13	-4334.080	-2674.469	518.974		
14	436.1112	9.9079	83.309	85.000	
15	149728.5	103.29868	54.42188	152118.4	100.60300
16	53.12845	941384.6	316.35024	6.16508	5127975.7
17	258.10896	-5.65882	7441957.1	306.77130	-9.30543
1	125.0000	103797.6	134871.4	-2702.8	3560.785
2	2697.908	-24.312	89.826	32.704	-9.111
3	135126.5410	103678.9307	4467.4929	5522.72461	37.4319
4	104.7818	29.1909	100.6168	80.24897	28.4551
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	4521.525
7	-0.5194	0.3192	72.8168	72.0815	4.1996
8	0.0000071	110.678	32201.371	122757.408	-1116.068
9	1100.4802	20744.7609	-17.2944		
10	272552.7	133203.3	-48800.1	4884.718	2851.539
11	-405.147	-890.366	-269544.082	-177.756	-21.820
12	-41253.420	-1.134	-16463287.250	8503595.9	9975739.9
13	-4698.484	-2954.726	499.124		
14	486.8539	5.8665	72.178	84.506	
15	170209.8	103.50838	52.40844	172695.0	101.38851
16	51.30139	929371.2	316.87910	7.10066	5116360.0
17	258.00244	-5.49069	7428701.0	306.80463	-9.18185

TABLE AP 7-1 (Sheet 3 of 10)
OBSERVED TRAJECTORY TABULATION

1	110.6300	122735.2	148769.4	-2827.1	4026.969
2	2861.976	-24.738	97.408	33.485	-0.235
3	149126.3125	121801.2236	4961.6016	6060.81958	35.7535
4	104.8275	28.4812	101.0189	80.19760	29.4422
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	5019.601
7	-0.5607	C.5653	40.3675	51.0212	4.7136
8	0.0000042	117.351	38051.179	193373.862	-1706.827
9	1244.1454	2171.7871	-18.9483		
10	298117.3	146853.5	-50839.5	5153.851	2810.990
11	-410.046	-1064.913	-290718.406	-183.052	-24.032
12	-4314.298	-0.942	-164875251.125	6490072.5	9978176.4
13	-3085.652	-1262.850	432.769		
14	470.3551	3.4088	97.421	74.526	
15	192883.5	103.69046	50.46966	195459.5	101.96895
16	49.52026	915995.5	317.49686	8.13172	5103102.1
17	257.44124	-4.30962	7411549.4	306.84243	-0.04818
1	135.0000	144127.3	163515.4	-2958.7	4532.612
2	3032.579	-26.772	105.315	33.990	-0.328
3	164026.8710	142928.1152	5453.6060	6586.19599	34.1759
4	104.8712	27.7506	101.3733	80.12902	28.4273
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	5529.592
7	-0.5102	0.1806	88.3925	34.8832	5.0751
8	0.0000021	124.290	44661.274	144476.019	-1307.370
9	1293.9169	2269.2780	-21.0413		
10	326191.5	160316.2	-52910.2	5862.603	2972.187
11	-417.120	-1130.996	-312686.531	-187.548	-25.638
12	-4472.952	-0.414	-169139??.750	6472916.5	9980462.6
13	-3495.954	-1602.606	440.015		
14	494.1806	1.9348	98.425	83.082	
15	217987.3	103.82385	49.60000	220649.6	102.26791
16	47.78144	901180.4	314.32017	9.27222	5088091.4
17	257.74353	-5.11453	7396290.0	306.88522	-8.90417
		139.57	S-1B INBOARD ENGINE CUTOFF COMMAND		
1	139.5700	165976.4	177737.9	-3086.3	5026.117
2	3189.405	-28.281	112.927	34.492	-0.427
3	176389.6027	164483.2969	5944.3616	7098.33801	32.8368
4	104.9183	27.0882	101.6760	80.06418	28.4120
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	5913.284
7	0.2574	-0.0408	96.2016	23.3216	5.4040
8	0.0000013	131.075	51408.726	155053.115	-1408.706
9	1552.6178	2358.9038	-23.0801		
10	356085.5	175245.7	-56833.1	6361.104	3121.628
11	-423.843	-1257.202	-335358.405	-191.894	-26.826
12	-4617.758	-0.648	-169400031.625	8455682.3	9982393.4
13	-5891.366	-3938.944	403.450		
14	498.4410	1.1409	99.175	279.977	
15	243204.1	103.93668	48.95481	245941.3	102.57170
16	46.24154	886384.2	318.98841	10.42145	5072720.3
17	257.60204	-4.92341	7378539.7	306.92906	-8.76255
		143.47	S-1B OUTBOARD ENGINE CUTOFF COMMAND		
1	143.4700	186105.4	190238.3	-3194.6	5263.686
2	3207.267	-27.829	57.078	2.447	5.124
3	191057.5479	184321.5898	6143.9053	7317.14910	31.8592
4	104.9657	26.4124	101.8266	80.00452	28.3980
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	6161.905
7	0.0000	-0.0000	103.0405	16.0850	5.7113
8	0.0000004	66.682	57624.534	164147.059	-1501.452
9	1675.5756	2400.4784	-23.9733		
10	374616.5	187671.3	-56494.0	6598.276	3134.613
11	-426.421	-1371.867	-351704.699	-193.129	-31.016
12	-4761.173	-0.496	-169633?2.375	8439924.6	9983489.1
13	-6034.646	-4122.919	358.074		
14	476.8530	0.6899	0.000	0.000	
15	260149.4	104.01529	45.62486	268944.6	102.79507
16	44.98649	873069.0	319.72401	11.47412	5058540.4
17	257.47091	-4.75302	7362103.5	306.96957	-8.63606
		144.27	S-1B/S-IVD SEPARATION COMMAND		
1	144.0000	188900.4	191937.3	-3213.3	5273.294
2	3199.671	-27.657	13.127	-18.209	5.194
3	192781.1906	187074.8867	6168.1679	7322.84512	31.8501
4	104.9720	26.3522	101.8160	79.99825	28.3960
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	6164.168
7	0.0000	-0.0000	103.9187	14.9691	5.8081
8	0.0000004	18.737	58447.789	165815.441	-1514.169
9	1678.6172	2403.1250	-24.0205		
10	367919.0	189111.8	-56720.0	6608.012	3126.339
11	-426.555	-1390.388	-353275.937	-193.383	-31.325
12	-4757.943	-0.475	-169665?2.875	8437735.1	9984088.1
13	-6033.853	-4134.051	352.117		
14	469.5089	0.6339	0.000	0.000	
15	269320.3	104.02543	45.49262	272124.9	102.82246
16	44.82392	871245.2	319.82830	11.62034	5036971.5
17	257.45264	-4.72969	7359816.3	306.97519	-8.61673
1	144.2700	196325.5	192800.3	-3220.9	5274.144
2	3193.861	-27.533	8.517	-22.549	0.447
3	193657.1484	188478.3145	6165.8821	7320.92767	31.7136
4	104.9754	26.3114	101.8391	79.99202	28.3950
5	-0.0000000	-0.0000000	-0.0000000	-0.0000000	-0.0000000
6	-0.0000300	-0.0000000	-0.0000000	-0.0000000	6165.882
7	-0.0000	0.0000	104.4713	14.4131	5.8228
8	0.0000008	12.408	58927.878	166264.254	-1520.710
9	1674.9590	2403.8922	-24.0257		
10	384704.3	189974.7	-58835.4	6608.909	3120.316
11	-426.561	-1398.847	-355511.730	-193.512	-31.484
12	-4766.470	-0.484	-16568141.875	8436616.4	9984162.9
13	-6029.696	-4137.763	349.043		
14	466.7930	0.6073	-0.000	-0.000	
15	2709?5.1	104.03044	45.36589	273743.3	102.83610
16	44.76184	870318.0	319.88169	11.69489	5035367.5
17	257.44151	-4.71783	7358649.0	306.97806	-8.60991

	144.33	FIRST MOTION BETWEEN S-1B AND S-IVB STAGES			
1	144.3300	190642.2	192992.1	-3222.6	5274.333
2	3192.570	-27.506	7.491	-23.514	0.459
3	193851.7715	188790.1836	6165.3740	7320.53784	31.7033
4	104.9762	26.3023	101.8397	79.99109	28.3968
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	6165.375
7	0.0000	-0.0000	104.5201	14.2919	5.8761
8	0.0000004	11.002	59075.682	166408.504	-1522.151
9	1629.0304	2404.0627	-24.0269		
10	385101.1	190181.9	-58868.9	6609.109	3118.978
11	-426.562	-1400.737	-355707.177	-193.540	-31.519
12	-4768.367	-0.481	-16564501.875	8436387.9	9984181.4
13	-6028.777	-4137.977	348.360		
14	466.1898	C.6016	0.000	0.000	
15	271294.1	104.03152	45.34677	274103.1	102.83929
16	44.72174	870112.3	319.89357	11.71148	5033104.4
17	257.44124	-4.71519	7358190.7	306.97869	-8.60795
1	145.0000	194178.2	195127.0	-3241.1	5275.820
2	3175.558	-27.198	2.297	-28.871	0.559
3	196018.6307	192272.3223	6157.8557	7314.51454	31.6703
4	104.9846	26.1746	101.8471	79.98652	28.3923
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	6157.455
7	0.0000	-0.0000	105.6679	13.0951	5.9614
8	0.0000007	3.589	60117.854	168020.160	-1534.336
9	1627.9179	2405.1776	-24.0367		
10	389531.4	192247.6	-59147.0	6610.688	3101.455
11	-426.567	-1421.987	-358999.680	-193.640	-31.916
12	-4789.549	-0.434	-16572541.625	8433592.5	9984414.6
13	-6016.091	-4146.502	339.618		
14	459.4679	0.5408	0.000	0.000	
15	275299.6	104.04369	45.13554	278117.9	102.87199
16	44.52169	867870.4	320.02675	11.89680	5029554.4
17	257.41810	-4.68981	7355496.1	306.98584	-8.58612
		145.63	S-IVB ENGINE START COMMAND		
1	145.6300	197503.6	197121.6	-3258.4	5277.474
2	3156.037	-26.826	1.555	-30.649	0.542
3	198044.1680	195546.6016	6149.2289	7307.59521	31.6155
4	104.9914	26.0484	101.8549	79.97074	28.3900
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	6149.279
7	0.0000	-0.0000	106.7631	11.9062	5.9936
8	0.0000006	2.252	61145.064	169535.416	-1553.537
9	1630.2676	2405.1496	-24.0184		
10	393697.8	194195.2	-59415.9	6612.394	3081.450
11	-426.481	-1442.213	-360203.340	-194.105	-32.292
12	-4809.461	-0.408	-16576327.125	8430976.0	9986425.4
13	-6001.585	-4156.115	329.625		
14	453.1872	0.4897	0.000	0.000	
15	279060.9	104.05478	44.94056	281887.4	102.90197
16	44.33691	865673.9	320.15278	12.07110	5050512.4
17	257.39631	-4.65829	7352771.9	306.99253	-8.56566
1	150.0000	220614.8	210627.6	-3371.0	5309.711
2	3035.860	-25.492	15.945	-20.891	0.164
3	211778.2363	218269.0371	6116.3819	7286.11975	30.3965
4	105.0419	25.1357	101.9088	79.90244	28.3739
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	6114.142
7	0.0000	-0.0000	114.1847	6.2407	6.0382
8	0.0000019	19.433	66286.190	180048.314	-1659.221
9	1641.0557	2409.5019	-24.3152		
10	421643.4	207367.5	-59281.6	6645.069	2997.712
11	-427.258	-1589.202	-383342.180	-195.681	-35.011
12	-4947.478	-0.221	-16602155.000	8412651.1	9985916.3
13	-5923.987	-4233.718	263.778		
14	420.1695	0.2598	0.000	0.000	
15	305034.5	104.12462	43.66990	307916.8	103.08710
16	43.13106	850993.9	321.05079	13.28161	5034231.1
17	257.24431	-4.47032	7333792.0	307.03925	-8.47581
1	155.0000	247380.3	229554.5	-3444.4	5304.129
2	2935.694	-22.441	18.766	-19.291	0.621
3	227000.2188	244596.2813	6143.0462	7324.25867	29.2175
4	105.1161	24.2005	102.0077	79.82141	28.3549
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	6141.946
7	0.0000	-0.0000	121.7607	3.4487	6.3071
8	0.0000022	22.622	76500.665	192135.613	-1781.229
9	1664.6446	2425.6345	-24.3067		
10	456087.5	221892.2	-61418.8	6732.247	2852.945
11	-427.010	-1772.499	-408473.977	-196.024	-39.169
12	-5105.174	0.007	-16631893.375	8391200.4	9987060.1
13	-5892.175	-4346.210	193.708		
14	394.9274	0.1310	0.000	0.000	
15	334789.1	104.19067	42.35477	337727.7	103.26159
16	41.79479	834522.6	322.14102	14.84668	5013370.8
17	257.06698	-4.25912	7311715.7	307.09352	-8.26840
1	160.0000	274606.3	239997.1	-3601.7	5491.207
2	2840.816	-20.308	19.127	-18.114	9.427
3	241777.3965	271333.4961	6182.5555	7374.65524	24.0971
4	105.1807	23.2691	102.1019	79.74315	28.3357
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	6182.555
7	0.0000	-0.0000	129.7627	1.9190	6.5436
8	0.0000001	23.212	84981.953	204308.281	-1901.448
9	1698.9317	2444.2545	-24.4076		
10	489396.0	235909.2	-64356.7	6826.041	2751.288
11	-427.756	-1973.086	-434391.578	-199.385	-41.928
12	-5267.839	0.251	-16661101.875	8369186.5	9987956.1
13	-5868.903	-4463.863	176.971		
14	371.6569	0.0647	0.000	0.000	
15	364718.9	104.24851	41.14991	367708.4	103.40809
16	40.71862	818356.5	323.30873	16.11387	4996184.3
17	256.88512	-4.05100	7269157.6	307.24891	-8.11297
1	165.0000	302308.1	253966.6	-3695.9	5587.751
2	2746.935	-17.426	19.451	-18.758	0.534
3	256122.5918	298507.2695	6226.4687	7428.87915	26.0960
4	105.2526	22.3956	102.2020	79.66161	28.3161
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	6226.468
7	0.0000	-0.0000	137.5318	1.0076	6.7996
8	0.0000001	23.673	93556.913	216369.193	-2026.869
9	1729.7215	2461.0815	-24.6965		
10	526383.6	249428.9	-65694.9	6925.224	2654.533
11	-427.789	-2192.190	-461099.938	-193.493	-45.755
12	-5419.882	0.509	-16690594.375	8346551.5	9988306.9
13	-5847.318	-4581.925	55.744		
14	350.1513	0.0312	0.000	0.000	
15	394844.8	104.29952	40.03115	397880.4	103.53323
16	39.64076	802528.1	324.54189	17.57016	4978680.7
17	256.69854	-3.84580	7226104.0	307.20547	-7.99940

TABLE AP 7-1 (Sheet 4 of 10)
OBSERVED TRAJECTORY TABULATION

1	170.0300	330491.4	267464.2	-3776.7	5685.120
2	2654.084	-14.939	20.110	-18.294	0.471
3	272043.5352	328126.9492	6273.0588	7487.24219	25.9146
4	105.1701	71.5199	102.2985	79.57878	26.2961
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	6275.038
7	0.0000	-0.0000	145.0714	0.5152	7.0591
8	0.0000000	24.782	102281.550	228919.469	-2150.884
9	1761.1169	2479.1236	-24.9225		
10	5592553.7	2624536.1	-67834.9	7026.151	2554.699
11	-428.257	-2431.049	-4885591.961	-190.270	-49.830
12	-5576.938	0.783	-16719740.375	83233343.7	9988613.3
13	-5827.109	-4761.183	-13.070		
14	329.0140	0.0148	0.000	0.000	
15	4251794.6	104.34524	38.98152	4288257.9	103.64194
16	38.62599	787080.5	325.90881	19.05346	4956796.6
17	256.50708	-3.64342	7242548.9	307.26325	-7.40763

1	175.0300	359173.4	280510.2	-3845.4	5782.896
2	2563.420	-12.619	20.338	-17.917	0.579
3	283550.2305	356210.3594	6329.9845	7551.36499	24.8589
4	105.3855	70.6676	102.3941	79.49461	28.2756
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	6329.984
7	0.0000	-0.0000	152.3860	0.2490	7.1607
8	0.0000000	24.652	111167.430	241361.104	-2276.166
9	1793.5464	2497.7268	-25.2207		
10	5744029.2	2149998.6	-69937.7	7126.221	2660.918
11	-428.967	-2690.915	-5169868.590	-185.642	-54.159
12	-5733.724	1.071	-16746871.750	82799537.7	9988176.5
13	-5810.601	-4822.180	-81.432		
14	325.3700	0.0069	0.000	0.000	
15	4557147.6	104.38657	37.98778	4188865.4	103.73734
16	37.66228	772057.1	327.35941	20.56424	4936578.1
17	256.31055	-3.44373	7218476.2	307.32231	-7.65755

1	180.0900	388363.5	293108.8	-3896.6	5887.414
2	2678.296	-7.201	19.364	-16.646	1.299
3	298660.8438	382766.8945	6387.7736	7617.28699	23.8787
4	105.4611	69.8768	102.5124	79.40006	28.2547
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	6387.773
7	0.0000	-0.0000	159.4861	0.1709	7.2008
8	0.0000000	24.870	120215.660	253898.465	-2401.185
9	1825.4475	2517.6386	-24.5896		
10	6305113.0	2870711.4	-72118.1	7226.430	2370.618
11	-426.571	-2973.057	-5459028.789	-179.534	-56.741
12	-5890.336	1.375	-16777489.750	82751131.3	9987597.8
13	-5747.959	-4938.062	-149.353		
14	327.6121	0.0033	0.000	0.000	
15	4865573.5	104.42513	37.04144	4897728.4	103.62290
16	35.74217	757513.3	328.92377	22.10168	4916008.5
17	256.10872	-3.24652	7193877.6	307.38265	-7.50899

1	185.0000	418038.5	305306.9	-3917.4	5981.641
2	2702.821	-1.069	18.219	-14.472	1.242
3	309470.2461	411773.8008	6446.2068	7682.64008	23.0129
4	105.5623	69.1833	102.6323	79.32223	28.2333
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	6446.206
7	0.0000	-0.0000	166.3931	0.0943	7.2943
8	0.0000000	24.933	129419.708	286544.473	-2522.059
9	1855.8452	2541.0228	-23.7535		
10	6668845.5	2987118.2	-74263.4	7321.188	2289.940
11	-423.511	-3278.757	-5757771.547	-171.870	-61.582
12	-6046.749	1.693	-16806856.500	82501701.1	9986691.6
13	-5784.885	-5045.321	-212.023		
14	348.2103	0.0017	0.000	0.000	
15	5176711.2	104.46308	36.14061	5208804.4	103.90199
16	35.64431	763539.7	330.61061	23.66612	4895119.6
17	255.90150	-3.05134	7168780.2	307.44415	-7.36164

1	190.0000	448169.9	317136.3	-3907.8	6071.159
2	2728.439	4.890	18.747	-14.551	1.232
3	321861.4414	441202.7305	6502.6857	7745.50311	22.1958
4	104.6606	68.5463	102.7475	79.23419	28.2115
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	6502.685
7	0.0000	-0.0000	173.1260	0.0799	6.9060
8	0.0000000	25.286	138771.156	279308.395	-2636.852
9	1864.8922	2564.4921	-22.9753		
10	7037144.8	3059470.3	-76353.6	7411.385	2210.721
11	-420.624	-3609.313	-6006395.883	-162.577	-65.684
12	-6202.967	2.026	-16835782.250	82246885.6	9985479.9
13	-5746.314	-5148.436	-272.811		
14	368.2590	0.0009	0.000	0.000	
15	5490641.5	104.50041	35.28312	5522762.9	103.97561
16	35.02714	730240.6	332.42959	25.25532	4873963.0
17	255.68900	-2.85787	7143216.6	307.50678	-7.21528

1	195.0000	478769.3	326605.0	-3867.3	6168.998
2	2754.939	11.191	19.443	-14.037	1.267
3	333944.1711	471065.8633	6569.5872	7818.34253	21.4014
4	105.7826	67.8908	102.8684	79.14492	28.1892
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	6569.587
7	0.0000	-0.0000	179.6953	0.0160	6.7396
8	0.0000000	26.241	148273.988	292192.063	-2751.506
9	1916.4793	2589.0942	-22.0091		
10	7416215.5	3208834.6	-78448.6	7509.487	2139.408
11	-417.303	-3966.034	-6378000.836	-151.581	-74.049
12	-6358.995	2.374	-16866478.000	81986876.6	9983965.1
13	-5778.357	-5256.006	-333.900		
14	393.6486	0.0005	0.000	0.000	
15	5807029	104.53718	34.46298	5839554.2	104.04461
16	34.27506	717689.6	334.39338	26.86507	4852473.2
17	255.47100	-2.66598	7117176.8	307.57059	-7.06981

1	200.0000	509855.8	339719.7	-3794.9	6265.676
2	2786.459	17.694	19.632	-14.605	1.333
3	345828.0899	501382.2031	6636.2352	7890.74384	20.8097
4	105.9317	67.2551	102.9862	79.05436	28.1865
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	6636.235
7	0.0000	-0.0000	186.1015	0.0090	6.5446
8	0.0000000	25.949	157934.289	305197.375	-2859.850
9	1947.7237	2612.8295	-21.2264		
10	7768805.4	3313186.3	-80527.7	7606.528	2057.438
11	-414.176	-4350.247	-6609485.469	-138.809	-79.680
12	-6514.838	2.737	-16893558.250	81721276.2	9982139.8
13	-5773.869	-5363.924	-395.853		
14	424.2473	0.0003	0.000	0.000	
15	6126795	104.57353	33.67495	6159958.9	104.10979
16	33.45319	705962.2	336.91391	28.48958	4830700.1
17	255.24724	-2.47549	7090643.3	307.63562	-6.92513

1	205.0300	541431.0	350669.2	-3689.4	6364.619
2	2113.110	24.864	19.969	-14.546	1.477
3	357354.1094	532154.4063	6706.3833	7904.34650	19.8251
4	105.9855	66.6250	103.1004	78.96750	28.1433
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	6706.383
7	0.0000	-0.0000	192.3470	0.0054	6.3821
8	0.0000000	26.234	167752.840	318320.176	-2963.518
9	1974.7008	2636.2699	-20.7022		
10	8176065.6	3416408.7	-82589.5	7705.802	1974.681
11	-410.439	-4763.288	-7029948.852	-126.195	-85.581
12	-6670.449	3.113	-16922417.500	81450311.8	9980902.5
13	-5769.846	-5471.667	-459.206		
14	453.0015	0.0002	0.000	0.000	
15	6449772.2	104.60955	32.91439	6482778.2	104.17175
16	32.70718	699141.1	338.81058	30.11954	4808623.6
17	255.01757	-2.28636	7063610.7	307.70192	-6.78128

1	210.0300	573503.0	360852.8	-3547.9	6465.161
2	2039.969	31.877	20.219	-14.720	1.420
3	368573.5547	563392.9453	6779.4705	8044.58325	19.0467
4	106.0902	66.0055	103.2314	78.86932	28.1195
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	6779.420
7	0.0000	-0.0000	196.4165	0.0032	6.1158
8	0.0000000	26.196	177132.984	331559.841	-3061.808
9	2012.3569	2659.3662	-19.1214		
10	8558865.9	3511104.8	-84631.8	7806.506	1899.623
11	-406.503	-5206.513	-7366990.086	-107.691	-91.754
12	-6825.982	3.504	-16951258.000	81171187.8	9977546.8
13	-5766.635	-5594.580	-523.198		
14	502.3584	0.0001	0.000	0.000	
15	6773949.9	104.66554	32.11782	6809925.9	104.23170
16	31.98176	685312.4	341.29134	31.74451	4786241.0
17	254.78173	-2.09915	7036067.8	307.76949	-6.63823

1	215.0000	606084.1	370868.2	-3370.8	6566.798
2	1966.115	38.931	20.584	-14.701	1.433
3	379487.0313	595154.8750	6854.9224	8125.00562	18.2970
4	106.1921	65.1953	103.3521	78.77440	28.0953
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	6854.927
7	0.0000	-0.0000	204.3754	0.0021	5.8508
8	0.0000000	26.067	187477.016	344915.414	-3154.443
9	2048.3515	2682.6104	-18.1055		
10	8951352.2	3604044.0	-86654.9	7904.308	1819.943
11	-402.765	-5681.290	-7712088.500	-89.124	-98.202
12	-6981.292	3.909	-16980081.750	80891864.5	9974770.1
13	-5763.506	-5696.711	-587.567		
14	557.9457	0.0001	0.000	0.000	
15	7105557.5	104.68133	31.46219	7139912.4	104.29831
16	31.28010	676569.8	343.97168	33.35135	4763549.5
17	254.53956	-1.91325	7008007.3	307.83839	-6.49598

1	220.0000	639177.1	380515.1	-3158.1	6670.652
2	1892.512	46.180	20.893	-14.763	1.459
3	390090.2539	627299.6250	6934.0709	8208.78003	17.5562
4	106.2944	64.7983	103.4735	78.67892	28.0709
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	6934.970
7	0.0000	-0.0000	210.0707	0.0014	5.6181
8	0.0000000	26.890	198187.893	358386.195	-3242.723
9	2079.0811	2705.6563	-17.0501		
10	934953.0	369305.1	-88659.0	8012.242	1740.193
11	-398.884	-6189.004	-806502.672	-68.518	-104.929
12	-7136.433	4.328	-17008896.000	80604618.5	9971670.0
13	-5761.723	-5810.415	-652.481		
14	611.3370	0.0001	0.000	0.000	
15	7438746.0	104.71690	30.76584	7472751.6	104.34334
16	30.59465	669009.6	346.86406	34.92464	4740346.5
17	254.29083	-1.72882	6979420.6	307.90868	-6.35447

1	225.0000	672793.1	389793.3	-2908.4	6775.984
2	1818.791	53.604	21.217	-14.688	1.373
3	400403.7910	659986.6719	7016.0408	8295.10095	16.8116
4	106.3970	64.2134	103.5952	78.58163	28.0452
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	7016.040
7	0.0000	-0.0000	215.6526	0.0010	5.3236
8	0.0000000	27.203	208668.695	371971.781	-3325.177
9	2113.3257	2728.5743	-15.9597		
10	975277.0	377807.6	-90643.2	8117.585	1667.609
11	-394.874	-6731.056	-8425572.105	-45.825	-111.938
12	-7291.408	4.760	-17037702.500	80310784.6	9968244.3
13	-5760.590	-5925.276	-717.937		
14	698.6698	0.0000	0.000	0.000	
15	777538.5	104.75230	30.08626	780957.8	104.39657
16	29.92507	662729.4	349.97866	36.44662	4717279.6
17	254.03530	-1.54584	6950297.8	307.98040	-6.21366

1	230.0000	706939.6	398701.9	-2673.2	6882.869
2	1765.431	60.617	21.525	-14.524	1.455
3	410413.9570	693174.3359	7101.0023	8384.15137	16.1274
4	106.4948	63.6442	103.7130	78.48294	28.0193
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	7101.002
7	0.0000	-0.0000	221.0736	0.0007	5.0701
8	0.0000000	27.534	219322.064	385672.047	-3402.703
9	2148.1184	2751.5280	-15.0139		
10	1016131.6	385911.9	-92669.0	8226.415	1581.104
11	-391.525	-7308.857	-8794116.398	-26.017	-119.291
12	-7446.222	5.206	-17066501.750	80011163.4	9964491.6
13	-5760.385	-6041.405	-783.205		
14	801.4553	0.0000	0.000	0.000	
15	8116274.8	104.78739	29.47218	8150044.6	104.44805
16	29.27015	657829.9	353.32706	37.89716	4693597.1
17	253.77276	-1.36424	6920632.0	308.05361	-6.07352

1	235.0000	741624.4	407248.6	-2301.6	6991.259
2	1672.202	67.998	21.841	-14.737	1.458
3	420130.1523	726870.8750	7188.8107	8475.77710	15.4411
4	106.5942	63.0884	103.8325	78.38280	27.9929
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	7184.810
7	0.0000	0.0000	226.3357	0.0005	4.7850
8	0.0000000	27.713	230150.729	399687.063	-3475.150
9	2183.4307	2774.9149	-13.9747		
10	1057523.7	393819.0	-94559.8	8332.713	1501.533
11	-387.497	-7823.844	-9170334.156	6.252	-128.813
12	-7600.879	5.665	-17095307.750	79706663.1	9960431.1
13	-5761.048	-6158.585	-849.111		
14	900.3818	0.0000	0.000	0.000	
15	8440886.8	104.82218	28.77738	8495526.5	104.49798
16	28.62882	654408.9	358.89553	39.25442	4669848.7
17	253.50298	-1.18398	6890415.0	308.12835	-5.93397

TABLE AP 7-1 (Sheet 5 of 10)
OBSERVED TRAJECTORY TABULATION

1	240.0000	776855.5	415429.2	-1943.5	7101.414	
2	1598.321	75.272	22.167	-14.795	1.472	
3	479351.8472	7212085.0859	7279.4490	8570.02016	14.7674	
4	106.6924	12.5418	103.9504	78.26121	27.9660	
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
6	0.0000000	0.0000000	0.0000000	0.0000000	7279.449	
7	0.0000	0.0000	231.4400	0.0004	4.5988	
8	0.0000000	27.966	2411157.412	413415.765	-3542.579	
9	2219.1334	2797.0296	-12.9879			
10	10994461.5	4509526.2	-96483.9	8442.636	1421.225	
11	-385.747	-8577.472	-955526.811	35.750	-134.686	
12	-7755.181	6.157	-17124115.000	7939574.7	9955999.8	
13	-5762.015	-6277.430	-915.604			
14	945.5266	0.0000	0.000	0.000		
15	880957.2	104.85864	28.13562	884415.7	104.54643	
16	27.99988	652558.5	0.69349	40.49517	4645383.2	
17	253.22571	-1.00504	6859640.5	308.20470	-5.79501	

1	245.0000	812640.6	423231.6	-1549.1	7212.879	
2	1524.076	82.454	22.524	-14.911	1.435	
3	438688.2227	7956625.2578	7372.5999	8666.55640	14.1092	
4	106.7484	12.0065	104.0664	78.17813	27.9184	
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
6	0.0000000	0.0000000	0.0000000	0.0000000	7372.599	
7	0.0000	0.0000	236.3868	0.0003	4.4498	
8	0.0000000	28.219	2523344.803	427457.102	-3605.113	
9	2253.7158	2819.4493	-12.0473			
10	11141952.0	4078430.8	-94893.6	8553.827	1345.428	
11	-388.176	-9271.203	-994587.594	67.642	-142.853	
12	-7909.734	6.822	-17159228.500	7907857.1	9951259.6	
13	-5763.277	-6397.546	-982.500			
14	1086.9817	0.0000	0.000	0.000		
15	916248.7	104.89078	27.51090	919725.4	104.59358	
16	27.3620	652364.3	4.70184	41.59624	4620800.0	
17	252.94069	-0.82741	6828297.8	308.28270	-5.65639	

1	250.0000	848988.5	430666.3	-1118.5	7326.545	
2	1449.960	89.822	22.845	-14.707	1.488	
3	447527.6094	8311101.1953	7469.1846	8766.29016	13.4691	
4	106.8648	11.4949	104.1837	78.07355	27.9103	
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
6	0.0000000	0.0000000	0.0000000	0.0000000	7469.184	
7	0.0000	0.0000	241.1763	0.0003	4.3271	
8	0.0000000	28.611	2637115.973	441610.230	-3682.963	
9	2292.6376	2841.6231	-11.0717			
10	11465001.8	4143310.7	-100285.4	8667.169	1259.627	
11	-376.477	-10006.523	-1034521.188	101.991	-151.323	
12	-8063.969	7.120	-17181750.000	7875596.4	9946173.5	
13	-5765.779	-6519.294	-1049.992			
14	1174.4212	0.0000	0.000	0.000		
15	951974.5	104.92450	26.89725	955468.6	104.63940	
16	26.77549	653904.1	8.89687	42.53572	4595897.6	
17	252.66767	-0.85107	6796379.1	308.36242	-5.51869	

1	255.0000	885904.3	437731.6	-650.5	7441.634	
2	1376.049	97.282	23.192	-14.726	1.491	
3	456084.8359	8669722.2969	7568.4158	8868.44214	12.8490	
4	106.9810	10.9186	104.3004	77.96763	27.8816	
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
6	0.0000000	0.0000000	0.0000000	0.0000000	7568.415	
7	0.0000	0.0000	245.8123	0.0002	4.2275	
8	0.0000000	28.911	2752731.977	455875.347	-3715.456	
9	2330.4656	2864.1771	-10.0883			
10	11746629.6	4204277.5	-102158.4	8781.831	1179.904	
11	-372.740	-10784.937	-1075226.656	138.863	-160.093	
12	-8218.302	7.631	-17210587.500	7846792.6	9940756.4	
13	-5769.118	-6662.073	-1117.788			
14	1259.1750	0.0000	0.000	0.000		
15	988150.8	104.95790	26.29416	991661.8	104.68409	
16	26.17865	657247.5	13.24480	43.29491	4570877.6	
17	252.34636	-0.87595	6763876.1	308.44392	-5.38123	

1	260.0000	923407.8	444428.7	-1145.9	7558.669	
2	1307.176	104.490	23.570	-14.677	1.516	
3	464361.3359	9032971.2500	7670.6767	8971.35127	12.2512	
4	107.0759	10.4896	104.4160	77.85975	27.8523	
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
6	0.0000000	0.0000000	0.0000000	0.0000000	7670.626	
7	0.0000	0.0000	250.2962	0.0002	4.1457	
8	0.0000000	29.276	2870121.629	470252.406	-3763.953	
9	2366.6996	2886.6270	-9.1428			
10	12728424.9	4276121.5	-104013.1	8898.194	1099.636	
11	-369.115	-11607.965	-1116701.453	178.321	-169.170	
12	-8371.926	8.154	-17239444.750	7809172.1	9934996.1	
13	-5773.729	-6766.046	-1185.654			
14	1340.1502	0.0000	0.000	0.000		
15	1024791.7	104.99094	25.70110	1028318.5	104.72769	
16	25.59162	662452.2	17.70164	43.85922	4545141.1	
17	252.01644	-0.90200	6731781.6	308.52726	-5.24416	

1	265.0000	961495.0	450758.6	396.1	7676.691	
2	1229.095	112.074	23.960	-14.795	1.459	
3	472362.6555	9402334.6875	7775.2696	9080.51184	11.8696	
4	107.1667	10.0125	104.5306	77.75049	27.8224	
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
6	0.0000000	0.0000000	0.0000000	0.0000000	7775.269	
7	0.0000	0.0000	254.4111	0.0002	4.0749	
8	0.0000000	29.567	2988961.699	484761.344	-3807.111	
9	2407.4243	2908.9017	-8.2741			
10	13176094.4	4314113.2	-105849.6	9015.870	1017.929	
11	-365.545	-12477.151	-1158945.547	220.476	-178.556	
12	-8525.212	8.690	-17268529.500	7775030.6	9928897.4	
13	-5778.721	-6691.276	-1251.963			
14	1417.8491	0.0000	0.000	0.000		
15	1061911.1	105.02360	25.11783	1065953.3	104.77024	
16	25.01139	669651.0	22.21714	44.21971	4519290.1	
17	251.71768	-0.12916	6697084.1	308.61253	-5.10742	

1	270.0000	1000180.2	456719.3	975.0	7797.560	
2	1155.015	119.505	24.214	-14.875	1.499	
3	480089.4141	9777345.7188	7883.5674	9191.15430	11.1010	
4	107.2629	9.5456	104.6450	77.61962	27.7919	
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
6	0.0000000	0.0000000	0.0000000	0.0000000	7883.567	
7	0.0000	0.0000	258.8182	0.0002	4.0240	
8	0.0000000	29.767	3110997.727	499341.176	-3846.188	
9	2447.0423	2930.9583	-7.3151			
10	13629289.0	4386300.2	-107868.7	9136.136	936.640	
11	-362.034	-13396.052	-1201958.250	265.242	-188.257	
12	-8619.365	9.238	-17287234.500	7740254.8	9922455.0	
13	-5784.719	-7018.812	-1323.125			
14	1492.3653	0.0000	0.000	0.000		
15	1099524.0	105.05584	24.54315	1103080.9	104.81176	
16	24.44402	678609.1	26.71631	44.37349	4493126.1	
17	251.38972	0.04258	6662785.9	308.69979	-4.97097	

1	275.0000	1039472.9	462168.3	1591.1	7920.080	
2	1080.652	126.962	24.032	-14.769	1.497	
3	487343.0586	10136840.5859	7994.4730	9304.23403	10.5499	
4	107.3556	9.0937	104.7508	77.52712	27.7407	
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
6	0.0000000	0.0000000	0.0000000	0.0000000	7994.473	
7	0.0000	0.0000	262.8576	0.0001	3.9803	
8	0.0000000	30.377	3236132.922	514050.574	-3880.535	
9	2487.2212	2952.8349	-6.4192			
10	13408972.8	4407718.6	-109670.2	9257.918	854.890	
11	-358.535	-14360.251	-1245738.625	312.029	-199.276	
12	-8832.809	9.798	-17326173.000	7704690.6	9915665.1	
13	-5791.221	-7147.769	-1392.829			
14	1561.7135	0.0000	0.000	0.000		
15	1137644.3	105.08769	23.97718	1141215.5	104.85235	
16	23.88281	689605.5	31.20198	44.32444	4466645.3	
17	251.05222	0.21324	6627885.5	308.76912	-4.43477	

1	280.0000	1079373.8	467570.8	2244.4	8041.724	
2	1004.669	134.352	23.604	-14.515	1.445	
3	494722.7656	10543521.2031	8104.8558	9416.65674	10.0077	
4	107.4474	8.4432	104.8710	77.43278	27.7259	
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
6	0.0000000	0.0000000	0.0000000	0.0000000	8104.855	
7	0.0000	0.0000	266.7490	0.0001	3.9515	
8	0.0000000	31.188	3359967.840	526867.844	-3913.411	
9	2527.0544	2974.1584	-5.5545			
10	13655661.0	4468844.0	-111254.1	9378.284	771.453	
11	-355.125	-15377.346	-1290286.813	363.747	-204.516	
12	-8950.285	9.371	-17355138.750	7668781.3	9908526.1	
13	-5795.565	-7278.312	-1462.931			
14	1625.9553	0.0000	0.000	0.000		
15	1176277.1	105.11913	23.41934	1179861.8	104.49202	
16	23.32967	702550.6	35.56767	44.04254	4439860.5	
17	250.70492	0.38277	6592324.8	308.88059	-4.49883	

1	285.0000	1119893.3	472358.3	2934.5	8164.812	
2	930.402	141.777	26.176	-14.250	1.557	
3	501612.8398	10937984.8438	8220.8617	9534.50537	9.4930	
4	107.5384	8.2154	104.9833	77.29717	27.6964	
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
6	0.0000000	0.0000000	0.0000000	0.0000000	8220.861	
7	0.0000	0.0000	270.4944	0.0001	3.9445	
8	0.0000000	31.850	3487066.062	543792.977	-3936.169	
9	2546.1249	2995.9089	-4.7117			
10	13927763.7	4484454.4	-113021.7	9503.032	689.541	
11	-351.776	-16446.959	-1335601.375	416.557	-219.283	
12	-9139.557	10.955	-17384135.500	7632072.5	9901035.8	
13	-5803.563	-7407.741	-1533.255			
14	1675.3493	0.0000	0.000	0.000		
15	1215438.6	105.15012	22.86936	1219036.4	104.93078	
16	22.78371	717436.9	39.76101	43.66318	4412771.9	
17	250.34746	0.55124	6556155.1	308.97429	-4.56308	

1	290.0000	1161054.0	476831.1	3667.6	8296.655	
2	857.866	149.394	25.528	-14.823	1.537	
3	508289.3711	11336895.8438	8342.0275	9657.32397	9.0084	
4	107.6299	7.8117	105.0964	77.17963	27.6632	
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
6	0.0000000	0.0000000	0.0000000	0.0000000	8342.027	
7	0.0000	0.0000	274.1021	0.0001	3.9433	
8	0.0000000	31.031	3616594.961	558828.609	-3957.521	
9	2610.9286	3018.0928	-3.8434			
10	14506603.3	4517745.2	-114771.8	9631.797	609.171	
11	-348.331	-17570.731	-1381682.031	472.817	-233.241	
12	-9292.704	11.551	-17413185.500	7594696.9	9893193.4	
13	-5815.051	-7541.673	-1603.837			
14	1732.7284	0.0000	0.000	0.000		
15	1255160.2	105.18074	22.32725	1258770.5	104.98475	
16	22.24556	734256.2	43.81603	43.08593	4385376.1	
17	249.97934	0.71886	6519138.2	309.07012	-4.42739	

1	295.0000	1202856.1	480936.3	4428.7	8425.404	
2	784.703	157.046	26.089	-14.795	1.505	
3	516692.4805	11742185.7344	8463.4766	9780.10449	8.9111	
4	107.7212	7.4161	105.2088	77.06035	27.6294	
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
6	0.0000000	0.0000000	0.0000000	0.0000000	8463.478	
7	0.0000	0.0000	277.5731	0.0001	3.9453	
8	0.0000000	31.543	3746415.590	573973.454	-3974.927	
9	2653.4521	3039.8639	-2.9791			
10	15025881.8	4545587.0	-116304.7	9759.978	527.566	
11	-344.888	-18750.325	-1426528.141	532.087	-243.613	
12	-9445.741	12.159	-17442265.250	7556655.4	9884998.8	
13	-5825.252	-7675.655	-1674.875			
14	1768.1180	0.0000	0.000	0.000		
15	1295448.3	105.21095	21.79275	1299070.8	105.00591	
16	21.71480	752976.5	47.64066	42.37201	4357687.1	
17	249.60026	0.88560	6481671.8	309.16876	-4.29157	

1	300.0000	1245314.4	484672.6	5212.4	8557.232	
2	710.239	164.627	26.534	-14.799	1.518	
3	520845.5977	12153674.9906	8548.2141	9904.47803	8.8711	
4	107.8114	7.0370	105.3702	76.93910	27.5948	
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
6	0.0000000	0.0000000	0.0000000	0.0000000	8548.214	
7	0.0000	0.0000	280.9091	0.0001	3.9516	
8	0.0000000	31.985	3881590.969	589226.938	-3987.169	
9	2696.8112	3081.4576	-2.1670			
10	15668207.4	4570720.2	-118270.9	9890.561	445.485	
11	-341.586	-19987.426	-1476139.125	594.423	-253.284	
12	-9598.658	12.778	-17471439.750	7517936.5	9876441.6	
13	-5836.409	-7811.799	-1746.559			
14	1811.5609	0.0000	0.000	0.000		
15	1340316.4	105.24075	21.26566	1339950.7	105.04211	
16	21.19121	773562.0	51.24143	41.54463	4329705.5	
17	249.20940	1.05151	6443748.3	309.26971	-4.15573	

1	305.0000	1288433.6	488039.0	6075.1	8690.706	
2	636.715	172.606	26.884	-14.841	1.873	
3	526751.9531	12571844.1406	8715.6718	10035.19031	7.6280	
4	107.9036	6.6610	105.4334	76.81647	27.5596	
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
6	0.0000000	0.0000000	0.0000000	0.0000000	8715.672	
7	0.0000	0.0000	284.1119	0.0001	3.9684	
8	0.0000000	32.316	4017844.787	604588.019	-3996.151	
9	2740.8167	3082.9518	-1.2481			
10	16197990.5	4590942.2	-119920.6	10022.921	361.210	
11	-337.959	-21283.760	-1526514.422	659.985	-265.290	
12	-9751.461	13.409	-17500651.250	7478535.1	9867530.6	
13	-5848.498	-7949.294	-1819.030			
14	1848.5077	0.0000	0.000	0.000		
15	1377780.4	105.27014	20.76568	1381425.6	105.07796	
16	20.67457	795971.0	54.61172	40.67741	4301437.6	
17	248.80755	1.21660	6404957.6	309.37328	-4.01976	

TABLE AP 7-1 (Sheet 6 of 10)
OBSERVED TRAJECTORY TABULATION

1	310.0000	13322724.8	4910346.1	6958.5	8826.027
2	561.777	180.227	27.266	-14.903	1.301
3	5326159.9688	1299614.3281	8845.7219	10164.42419	2.1993
4	107.9932	6.3011	105.5440	76.69182	27.5236	
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	8845.721	
7	0.0000	0.0000	247.1628	0.0001	3.9948	
8	0.0000000	32.644	4156000.270	620056.180	-4005.047	
9	2745.659	3104.2319	-0.4470			
10	1744419.8	448031.7	-1218011.4	101357.049	280.353	
11	-334.754	-22640.997	-1573653.438	728.528	-277.682	
12	-9924.154	14.050	-1752990.25.750	7438440.8	9858252.8	
13	-5661.019	-8088.616	-1891.814			
14	1873.9321	0.0000	0.000	0.000		
15	1419853.9	105.29926	20.23271	1423509.8	105.11303	
16	20.18474	8201.57.6	57.75215	39.67907	4272393.0	
17	248.34103	1.38089	6165491.2	309.47955	-3.49359	

1	315.0000	13376697.4	4933656.6	7877.8	9963.329
2	497.089	167.704	27.687	-14.899	1.540
3	5378139.1281	1362729.9063	8978.5156	10300.29932	6.7458
4	109.0410	5.9532	105.6524	76.55532	27.4969
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	8978.515
7	0.0000	0.0000	290.1244	0.0001	4.0256
8	0.0000000	33.061	4296640.680	635630.242	-4000.751
9	2830.8022	3125.3638	0.2454		
10	1749594.4	461869.5	-123267.9	10293.070	197.081
11	-331.764	-24080.450	-1623555.641	800.408	-290.378
12	-10056.737	14.704	-17559263.000	7397696.4	9848611.1
13	-5874.234	-8229.713	-1965.047		
14	1898.1435	0.0000	0.000	0.000	
15	1467550.4	105.82785	19.72652	1466216.7	105.14728
16	19.66151	844076.7	60.66820	38.58149	4244375.4
17	247.96565	1.54443	6325342.2	309.58864	-3.74718

1	320.0000	13421861.9	4959905.8	8835.5	9107.639
2	532.520	195.351	27.942	-14.874	1.539
3	5430264.8203	1366919.2188	9114.0794	10436.83203	6.3902
4	108.1696	5.6191	105.7632	76.43695	27.4494
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	9114.075
7	0.0000	0.0000	292.9383	0.0001	4.0345
8	0.0000000	33.334	4433909.633	651309.773	-3997.664
9	2878.0352	3146.4419	0.9832		
10	1751374.1	462622.6	-124919.0	10431.037	113.764
11	-326.619	-25595.374	-1674220.531	875.582	-303.451
12	-10209.214	15.168	-17588670.250	7356140.8	9836801.8
13	-5948.516	-8372.327	-2038.825		
14	1921.3073	0.0000	0.000	0.000	
15	1505885.4	105.35602	19.22697	1509581.4	105.18084
16	19.16478	873679.5	63.36973	37.49732	4214396.6
17	247.52553	1.70722	6264901.2	309.70069	-3.61044

1	325.0000	1467726.8	497783.1	9831.4	9243.468
2	316.784	203.037	28.437	-14.827	1.527
3	5479806.4453	1430994.4219	9252.0842	10575.71338	6.0131
4	106.7581	5.3001	105.8728	76.30668	27.4111
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	9257.084
7	0.0000	0.0000	295.6278	0.0001	4.0935
8	0.0000000	33.792	4508410.129	667094.828	-3993.935
9	2925.4906	3187.5455	1.7072		
10	1903677.6	462983.9	-126554.7	10570.656	30.623
11	-325.829	-27098.069	-1729647.469	954.103	-316.887
12	-10381.587	16.043	-17618150.500	7313921.5	9828222.8
13	-5933.899	-8516.193	-2117.862		
14	1941.3291	0.0000	0.000	0.000	
15	1549877.4	105.38378	18.73409	1553558.4	105.21375
16	18.67455	902919.5	65.86879	36.38972	4185862.4
17	247.07156	1.86934	6242962.1	309.81540	-3.47328

1	330.0000	1514302.1	499248.7	10866.0	9184.723
2	264.933	210.828	28.820	-14.788	1.564
3	5527201.7891	1476165.6406	9392.8022	10717.21375	5.6522
4	108.3469	4.9939	105.9825	76.17469	27.3721
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	9392.802
7	0.0000	0.0000	298.1965	0.0001	4.1106
8	0.0000000	34.234	4731345.746	682985.088	-3980.988
9	2970.4497	3184.5567	2.4366		
10	1957044.2	467928.8	-128175.2	10712.231	-52.713
11	-327.550	-28714.859	-1777836.016	1036.028	-330.690
12	-10511.856	16.729	-17647711.000	7270976.3	9817472.3
13	-5920.223	-8661.678	-2187.463		
14	1964.2912	0.0000	0.000	0.000	
15	1596527.2	105.41112	18.24772	1598221.7	105.24599
16	18.18070	933750.1	68.17882	35.27088	4156089.0
17	246.80149	2.03082	6200716.4	309.93412	-3.33582

1	335.0000	1561597.7	500424.0	11939.6	9531.844
2	190.015	218.022	29.274	-14.785	1.558
3	5572219.5391	1522043.4531	9516.2439	10861.35449	5.1087
4	108.4334	4.7018	106.0919	76.04035	27.3328
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	9539.241
7	0.0000	0.0000	300.6678	0.0001	4.1698
8	0.0000000	34.684	4881119.930	698980.370	-3966.651
9	3016.9310	3209.5565	3.1392		
10	2011001.5	462486.9	-129780.5	10855.803	-135.986
11	-319.548	-30403.593	-1830785.641	1121.409	-344.866
12	-10666.027	17.425	-17677356.000	7227299.8	9806147.8
13	-5937.704	-8808.756	-2262.422		
14	1984.2264	0.0000	0.000	0.000	
15	1639863.7	105.43805	17.76788	1643567.0	105.27763
16	17.71329	986128.1	70.31379	34.15075	4126287.9
17	246.14066	2.19171	6157757.4	310.05574	-3.19758

1	340.0000	1609625.4	501189.5	13052.2	9679.479
2	116.139	226.494	29.674	-14.715	1.607
3	5613546.6719	1568640.3438	9682.8251	11008.55725	4.9818
4	108.5241	4.4731	106.2014	75.90423	27.2917
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	9682.825
7	0.0000	0.0000	302.9850	0.0001	4.2171
8	0.0000000	35.116	5033536.684	713080.570	-3949.237
9	3067.8731	3230.5128	3.8364		
10	2069646.9	468569.1	-131370.8	11001.621	-219.102
11	-316.553	-32166.144	-1884495.875	1210.300	-359.618
12	-10818.094	18.133	-17707090.750	7182885.5	9794447.1
13	-5996.531	-8957.795	-2337.933		
14	1997.1423	0.0000	0.000	0.000	
15	1685898.6	105.44659	17.29448	1689610.1	105.30865
16	17.24211	1000012.6	72.28782	33.03719	4096270.2
17	245.62263	2.35207	6114035.7	310.18086	-3.05845

1	345.0000	1658397.0	503586.2	14204.4	9829.757
2	42.152	234.350	30.399	-14.652	1.589
3	5654650.7188	1615968.9063	9832.6412	11158.92712	4.6709
4	108.6172	4.1575	106.3104	75.76609	27.2502
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	9832.441
7	0.0000	0.0000	355.7116	0.0001	4.2670
8	0.0000000	33.757	5188035.176	731265.633	-3928.373
9	3117.7155	3251.4080	4.4981		
10	2121076.1	460264.9	-132946.3	11150.411	-302.722
11	-313.664	-33945.513	-1930960.219	1392.754	-376.393
12	-10970.071	19.851	-17736924.250	7137718.8	9782967.8
13	-5978.700	-9108.984	-2414.027		
14	2009.0670	0.0000	0.000	0.000	
15	1732648.2	105.49072	16.82746	1735367.7	105.33909
16	16.77724	1035366.2	74.11376	31.91649	4066051.1
17	245.10877	2.51194	6089602.5	310.30980	-2.91867

1	350.0000	1707927.0	504612.9	15396.4	9982.516
2	-31.707	242.476	30.781	-14.799	1.580
3	5695556.8797	1664044.5938	9983.5098	11312.26137	4.3736
4	108.7014	3.9030	106.4276	75.62549	27.2279
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	9983.509
7	0.0000	0.0000	307.7307	0.0001	4.3187
8	0.0000000	36.174	5345515.227	747594.344	-3904.121
9	3168.4093	3272.1329	5.1979		
10	2177154.9	458541.3	-134507.0	11301.407	-386.604
11	-310.660	-35905.574	-1984106.156	1598.824	-389.674
12	-11121.949	19.579	-17766859.750	7091792.8	9770705.4
13	-5997.910	-9262.172	-2490.985		
14	2020.1875	0.0000	0.000	0.000	
15	1780130.9	105.51648	16.36670	1783857.9	105.36896
16	16.31851	1072155.9	75.80493	30.95340	4035641.5
17	244.57863	2.67136	6074506.1	310.44217	-2.77801

1	355.0000	1758226.2	501269.5	16628.0	10137.529
2	-105.894	250.231	31.256	-14.910	1.553
3	5732668.3672	1712879.0313	10141.1694	11464.38147	4.0911
4	108.7488	3.8602	106.5286	75.48362	27.1847
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	10141.169
7	0.0000	0.0000	309.3656	0.0001	4.3721
8	0.0000000	36.609	5504685.656	764006.688	-3876.632
9	3219.6855	3292.7317	5.7840		
10	2234044.1	456398.5	-136053.4	11454.576	-470.805
11	-307.978	-37895.930	-2050185.234	1798.562	-405.392
12	-11273.731	20.316	-17796904.750	7045093.4	9758057.4
13	-6029.997	-9417.398	-2568.281		
14	2030.7284	0.0000	0.000	0.000	
15	1826361.6	105.54185	15.91213	1832096.0	105.39828
16	15.86588	1110346.6	77.37295	29.79159	4005066.4
17	244.03099	2.83035	5978598.4	310.57861	-2.63634

1	360.0000	1809306.4	500553.8	17899.0	10295.119
2	-180.366	258.198	31.986	-14.912	1.594
3	5767792.8125	1762484.8281	10299.9353	11627.53113	3.8218
4	108.8769	3.4284	106.6374	75.33922	27.1707
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	10295.915
7	0.0000	0.0000	311.2586	0.0001	4.4271
8	0.0000000	37.327	5667715.531	780521.406	-3846.206
9	3272.2450	3313.1546	6.3897		
10	2290104.8	453637.9	-137586.5	11610.245	-555.490
11	-305.243	-39967.908	-2106931.000	1602.018	-421.506
12	-11425.420	21.067	-17827061.750	6997615.5	9745521.5
13	-6063.149	-9574.774	-2646.440		
14	2040.7086	0.0000	0.000	0.000	
15	1877355.4	105.56679	15.46363	1881096.6	105.42701
16	15.41922	1149911.1	78.82860	28.75366	3974130.9
17	243.46581	2.98891	5931931.1	310.71925	-2.49356

1	365.0000	1861182.2	499465.7	19210.0	10454.579
2	-254.962	266.193	31.469	-14.934	1.569
3	580136.0781	1812877.4531	10461.0748	11789.00610	3.5666
4	108.9452	3.2081	106.7461	75.19268	27.0757
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	10461.074
7	0.0000	0.0000	313.0733	0.0001	4.4836
8	0.0000000	38.084	5832209.742	797138.047	-3812.802
9	3325.2745	3333.4544	6.9751		
10	2350151.2	450843.4	-139106.1	11767.708	-640.485
11	-302.563	-42111.566	-2164439.000	1709.245	-438.925
12	-11577.016	21.826	-17857338.750	6949342.1	9733592.1
13	-6067.067	-9733.727	-2725.108		
14	2050.1489	0.0000	0.000	0.000	
15	1927130.8	105.59135	15.02114	1930878.6	105.45521
16	14.97848	1190824.5	80.18192	27.74147	3943681.9
17	242.88215	3.14710	5884492.9	310.88423	-2.34956

1	370.0000	1913456.2	498005.1	20561.0	10616.909
2	-329.268	274.272	31.138	-14.821	1.619
3	583303.6094	1864060.6719	10625.1562	11953.37707	3.3275
4	109.0337	3.0012	106.8550	75.04387	27.0299
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	10625.154
7	0.0000	0.0000	314.7933	0.0001	4.5418
8	0.0000000	38.523	5999689.648	813456.016	-3776.921
9	3379.1613	3393.7531	7.5535		
10	2409305.7	447420.7	-140612.3	11927.574	-725.592
11	-299.896	-44343.637	-2227762.719	1820.292	-456.983
12	-11728.520	22.595	-17887734.750	6900275.6	9711769.6
13	-6092.374	-9894.555	-2804.268		
14	2059.0713	0.0000	0.000	0.000	
15	1977269.7	105.61552	14.58965	1981444.8	105.48289
16	14.54367	1233056.0	81.44175	26.75649	3912694.5
17	242.27943	3.30488	5836284.0	311.01372	-2.20422

1	375.0000	1967351.8	496173.8	21952.5	10781.689
2	-403.369	282.331	31.198	-14.884	1.621
3	586306.3828	1916056.2188	10792.9280	12121.39111	3.1037
4	109.1419	2.8074	106.9637	74.89304	26.9831
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	10792.926
7	0.0000	0.0000	316.4233	0.0001	4.6019
8	0.0000000	38.604	6170027.922	830675.438	-3737.395
9	3434.1440	3374.0118	8.0902		
10	2464031.4	443389.5	-142105.4	12090.620	-810.340
11	-297.358	-46861.784	-2281235.750	1935.211	-472.296
12	-11879.932	23.374	-17918265.000	6850393.2	9703549.0
13	-6119.430	-10057.978	-2844.064		
14	2067.5070	0.0000	0.000	0.000	
15	2029074.3	105.63930	14.15417	2032834.4	105.51003
16	14.11674	1276595.8	82.61654	25.77921	3881616.0
17	241.65879	3.46236	5787286.9	311.16798	-2.05738

TABLE AP 7-1 (Sheet 7 of 10)
OBSERVED TRAJECTORY TABULATION

1	360.0000	20216??.3	493974.0	23384.6	10948.822
2	-474.698	290.510	31.681	-12.992	1.642
3	569152.0406	196688?8.8926	10967.9594	122961.61309	2.9586
4	109.2312	2.6382	107.0729	74.73987	26.9353
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	10942.959
7	0.0000	0.0000	317.9600	0.0001	4.6632
8	0.0000000	39.822	6363??.563	847596.734	-3695.587
9	3483.8493	1393.0397	8.6683		
10	25302?96.0	439127.4	-1413585.8	12235.615	-892.672
11	-294.736	-49067.498	-23615?1.625	2054.049	-495.060
12	-12031.254	24.163	-17944933.000	6799693.6	9688929.1
13	-6149.035	-10721.826	-2963.122		
14	2075.4868	0.0000	0.000	0.000	
15	20617?2.1	105.66270	13.72965	2085047.9	105.53667
16	13.69173	1321423.5	83.71763	24.87026	3850285.3
17	241.01352	3.61955	5737497.7	311.52721	-1.90867
1	385.0000	20764??.4	491617.7	24857.8	11118.888
2	-550.781	298.693	34.300	-16.016	1.633
3	591861.0781	2022535.1563	11116.5271	124??.37219	2.7023
4	109.3196	2.4586	107.1815	74.58441	26.8566
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	11134.574
7	0.0000	0.0000	319.4197	0.0001	4.7264
8	0.0000000	39.349	651903.177	864622.867	-3651.081
9	3546.5204	3414.5170	9.1391		
10	2591992.6	434651.5	-145093.3	12421.353	-980.001
11	-292.327	-51563.099	-2402035.813	2176.658	-504.252
12	-12182.485	24.962	-17979756.250	6748186.7	9673912.5
13	-6177.459	-10190.018	-3045.011		
14	2083.0660	0.0000	0.000	0.000	
15	21343?7.2	105.68576	13.31141	21381C8.4	105.56283
16	13.27492	1367529.0	84.73971	23.97006	3819173.6
17	240.34685	3.77665	5686912.7	311.49164	-1.75845
1	390.0000	2132870.8	486676.5	26371.8	11291.639
2	-625.587	306.917	34.825	-16.778	1.660
3	594414.2734	2077095.2031	11313.1183	126??.11279	2.7166
4	109.4087	2.7966	107.2906	74.62666	26.8169
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	11313.118
7	0.0000	0.0000	320.8791	0.0001	4.7912
8	0.0000000	40.315	669779.614	881744.180	-3604.206
9	3604.1291	3434.2950	9.4327		
10	2654?3?6.3	4295?5.6	-146509.1	12593.734	-1066.254
11	-299.999	-54150.737	-2463326.000	2103.685	-526.478
12	-12333.626	25.771	-18010716.500	6895?93.3	9656481.6
13	-6207.617	-10559.849	-3127.002		
14	2090.1887	0.0000	0.000	0.000	
15	2188250.3	105.70839	12.89857	2197026.6	105.56848
16	12.86344	1414489.6	85.70087	23.09714	3787350.4
17	239.66193	3.93323	5835512.4	311.66156	-1.40623
1	395.0000	2189766.8	485162.2	27926.8	11467.064
2	-699.452	315.105	35.424	-14.760	1.677
3	596833.4531	2132421.1875	11492.6971	127821.81482	2.7488
4	109.4974	2.1501	107.3992	74.26655	26.7861
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	11492.697
7	0.0000	0.0000	322.1381	0.0001	4.8575
8	0.0000000	40.937	6879?46.084	898985.570	-3554.920
9	3667.6705	3494.2512	10.0459		
10	2717934.5	421960.5	-147957.8	12766.715	-1151.831
11	-287.659	-56832.591	-2525371.656	2414.579	-545.940
12	-12484.674	26.589	-18041835.000	6862564.8	9642661.8
13	-6219.724	-10731.566	-3209.107		
14	2096.9265	0.0000	0.000	0.000	
15	2243047.3	105.71067	12.49159	2246821.5	105.61167
16	12.45776	1461502.4	86.60251	22.25180	3756402.9
17	238.95194	4.08954	5932295.1	311.83722	-1.45189
1	400.0000	2247568.0	483481.1	29525.5	11646.004
2	-773.078	325.968	36.107	-14.701	1.681
3	599128.4844	2188678.9063	11676.1134	13005.32275	2.1960
4	109.5676	2.0166	107.5091	74.10406	26.7344
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	11676.115
7	0.0000	0.0000	323.3838	0.0001	4.9257
8	0.0000000	41.653	706?08.328	916286.773	-3503.403
9	3722.3993	3474.1990	10.5689		
10	2762208.1	418018.0	-149385.2	12943.187	-1237.345
11	-285.247	-59610.874	-2588172.313	2569.588	-565.449
12	-12635.636	27.417	-18073118.750	6588470.9	9626389.0
13	-6273.879	-10905.911	-3292.113		
14	2101.3079	0.0000	0.000	0.000	
15	22987?1.4	105.75258	12.09040	23025?7.9	105.63837
16	12.05780	1513160.9	87.44964	21.61343	3725715.0
17	238.21800	4.24580	5930251.3	312.01892	-1.29524
1	405.0000	2306??2.3	477432.7	31162.1	11878.170
2	-846.464	331.841	36.716	-14.720	1.631
3	601311.3906	2245855.9063	11863.0590	13192.34485	2.0570
4	109.6767	1.8950	107.6180	73.93913	26.6915
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	11861.058
7	0.0000	0.0000	324.5697	0.0001	4.9957
8	0.0000000	42.276	725??2.031	933707.947	-3449.823
9	3783.2767	3496.0925	10.9289		
10	2843?72.1	411617.5	-150805.9	13122.791	-1322.965
11	-283.193	-62487.827	-2651?27.594	2708.760	-585.409
12	-12786.504	28.254	-18104576.750	6533501.0	9609720.1
13	-6309.656	-11082.942	-3375.599		
14	2109.3644	0.0000	0.000	0.000	
15	2355338.4	105.77413	11.69501	2359128.7	105.66263
16	11.66359	1564463.2	88.24668	20.64144	3694722.7
17	237.45920	4.40141	5476371.4	312.20698	-1.13606
1	410.0000	2365835.2	473017.1	32642.3	12013.516
2	-919.834	340.347	37.486	-14.671	1.680
3	603390.0313	2303908.3438	12053.4650	13382.82307	1.9309
4	109.7672	1.7846	107.7281	73.77174	26.6276
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	12053.486
7	0.0000	0.0000	325.6961	0.0001	5.0672
8	0.0000000	43.079	744242.449	951227.539	-3393.999
9	3845.1414	3513.4907	11.3527		
10	2913441.4	404788.4	-152216.4	13305.505	-1408.767
11	-280.926	-65465.724	-2716038.969	2852.142	-605.827
12	-12937.280	29.100	-18136210.500	6477637.7	9592631.5
13	-6347.061	-11262.463	-3460.028		
14	2115.1263	0.0000	0.000	0.000	
15	2412881.6	105.79532	11.30136	2416676.2	105.68642
16	11.27506	1618606.6	88.99746	19.87502	3663865.0
17	238.87482	4.55697	5421646.6	312.40173	-0.97416

1	415.0000	2426376.8	468234.4	34364.9	12202.892
2	-993.366	345.715	38.210	-14.762	1.685
3	605375.4594	2362914.7500	12240.2227	135??.46718	1.8171
4	109.8589	1.6849	107.8375	73.60183	26.5724
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	12248.227
7	0.0000	0.0000	326.7732	0.0001	5.1404
8	0.0000000	43.794	763625.859	968866.250	-3336.749
9	3908.4010	3533.5312	11.6849		
10	2980434.3	387129.5	-153616.0	13402.187	-1495.006
11	-278.940	-68534.430	-2741099.969	2989.180	-676.710
12	-13087.983	29.957	-18160051.000	6420070.3	9575118.8
13	-6386.291	-11445.416	-3545.307		
14	2120.6198	0.0000	0.000	0.000	
15	2471382.5	105.81619	10.92141	2475180.8	105.70977
16	10.89217	1670392.7	89.70618	19.13339	3633181.1
17	235.66328	4.71225	5366066.5	312.60354	-0.90929
1	420.0000	2487867.3	463001.4	36129.4	12396.408
2	-1067.169	357.193	38.732	-14.820	1.704
3	607277.2500	2422871.8438	12445.3918	137??.60811	1.7142
4	109.9474	1.5947	107.9473	73.47937	26.5164
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	12445.391
7	0.0000	0.0000	327.8044	0.0001	5.2155
8	0.0000000	44.313	783227.672	986562.719	-3277.144
9	3972.4320	3552.9951	12.0154		
10	3048366.2	389838.2	-155006.2	13680.889	-1581.744
11	-277.030	-71733.605	-2846916.188	3151.727	-668.084
12	-13238.552	30.822	-18200082.500	6363140.9	9557177.8
13	-6426.299	-11630.209	-3631.295		
14	2125.8701	0.0000	0.000	0.000	
15	2530859.2	105.83661	10.94306	2534661.2	105.73267
16	10.51484	1725221.7	90.37555	18.41588	3602722.3
17	235.02424	4.86720	5309627.8	312.61280	-0.84124
1	425.0000	2550326.1	457565.1	38136.6	12589.451
2	-1140.093	365.662	39.317	-14.713	1.734
3	609105.3750	2483791.2500	12646.2563	139??.69275	1.6217
4	110.0380	1.5190	108.0572	73.25412	26.4491
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	12646.256
7	0.0000	0.0000	328.7946	0.0001	5.2918
8	0.0000000	44.985	803352.586	1006376.734	-3216.370
9	4037.6676	3572.6134	12.2983		
10	3117?36.3	381?71.2	-156386.9	13873.065	-1667.873
11	-275.228	-75028.300	-29134?5.094	3304.013	-669.895
12	-13389.046	31.696	-18232319.500	6304363.4	9538805.5
13	-6468.701	-11817.570	-3717.658		
14	2130.9112	0.0000	0.000	0.000	
15	2591328.2	105.85671	10.17034	2595133.7	105.75513
16	10.14309	1781294.1	91.00869	17.72115	3572532.9
17	236.15656	5.02177	5252310.7	313.02990	-0.66977
1	430.0000	2613?68.1	451678.9	39986.4	12787.902
2	-1214.379	374.270	40.054	-14.615	1.727
3	610869.9297	2545696.3750	12850.8843	14180.33289	1.5472
4	110.1294	1.4486	108.1677	73.07644	26.4307
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	12853.486
7	0.0000	0.0000	329.7509	0.0001	5.3698
8	0.0000000	45.774	823706.438	1022287.391	-3154.177
9	4104.0555	3591.7052	12.5836		
10	3187103.1	373195.1	-157758.5	14068.578	-1755.632
11	-273.408	-78433.359	-2980806.188	3468.700	-692.211
12	-13539.442	32.580	-18264769.750	6244999.0	9519797.8
13	-6511.708	-12008.216	-3805.961		
14	2135.7690	0.0000	0.000	0.000	
15	2642806.9	105.87644	9.40514	2646611.7	105.77717
16	9.77685	1818613.1	91.40851	17.04893	3547667.3
17	233.25927	5.17588	5194122.3	313.25528	-0.29461
1	435.0000	2678211.2	445424.5	41879.5	12989.783
2	-1287.411	382.936	40.727	-14.552	1.697
3	612381.7656	2608599.1563	13019.0396	14388.44950	1.4942
4	110.2213	1.3936	108.2784	72.89629	26.3610
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	13059.039
7	0.0000	0.0000	330.6778	0.0001	5.4493
8	0.0000000	46.505	844395.242	1040794.430	-3090.593
9	4171.6259	3611.0653	12.8398		
10	3257942.1	364160.5	-159171.1	14267.459	-1842.613
11	-271.675	-81951.221	-3046879.031	3633.827	-715.017
12	-13689.740	33.473	-18297442.000	6184477.5	9500750.0
13	-6557.362	-12201.180	-3893.698		
14	2140.4778	0.0000	0.000	0.000	
15	2715321.6	105.89586	9.44152	2719133.3	105.79878
16	9.41607	1897165.2	92.17684	16.39819	3511181.0
17	232.33139	5.32944	5135049.9	313.48942	-0.11550
1	440.0000	2743677.7	438805.9	43813.4	13195.354
2	-1350.155	391.528	41.491	-14.581	1.774
3	614257.2969	2672518.5625	13271.0466	14600.49597	1.4142
4	110.3130	1.3503	108.3690	72.71323	26.2801
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	13271.046
7	0.0000	0.0000	331.5839	0.0001	5.5303
8	0.0000000	47.295	865425.000	1058398.156	-3025.962
9	4240.4519	3630.8951	13.0280		
10	3329784.4	354731.8	-160475.5	14469.961	-1929.191
11	-270.156	-85584.358	-3117703.219	3801.439	-738.322
12	-13839.936	34.376	-18330347.500	6122982.0	9481060.1
13	-6605.003	-12397.112	-3982.474		
14	2145.0783	0.0000	0.000	0.000	
15	2778886.3	105.91491	9.08543	2782700.9	105.81997
16	9.06081	1957017.4	92.71650	15.76826	3484139.8
17	231.37194	5.48242	5075088.7	313.73282	0.00793
1	445.0000	2810171.3	431823.5	45795.1	13404.572
2	-1432.794	400.319	42.242	-14.497	1.741
3	615908.3828	2737473.3125	13466.8712	14816.31116	1.3965
4	110.4058	1.3179	108.5065	72.52741	26.2179
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	13484.970
7	0.0000	0.0000	332.4766	0.0001	5.6128
8	0.0000000	48.104	886801.984	1076598.188	-2960.276
9	4310.5217	3649.6169	13.2301		
10	3402448.2	344869.4	-161872.5	14676.039	-2016.155
11	-268.582	-89335.781	-3187278.031	3977.582	-762.132
12	-13990.030	35.285	-18363495.500	6060501.6	9460923.5
13	-6694.537	-12595.931	-4072.198		
14	2149.6056	0.0000	0.000	0.000	
15	2843524.3	105.93362	8.73484	2847341.6	105.84075
16	8.71102	2018118.1	93.22932	15.13835	3455991.5
17	230.37994	5.63471	5014231.6	313.98603	0.25800

TABLE AP 7-1 (Sheet 8 of 10)
OBSERVED TRAJECTORY TABULATION

1	480.0000	3077729.4	474478.4	47818.3	13617.936	1	485.0000	3381917.0	362991.1	69222.3	15236.539
2	-1525.132	409.049	42.071	-14.592	1.776	2	-2009.717	471.639	50.018	-15.088	1.781
3	617346.6438	2803481.2188	137084.9965	15036.02758	1.1707	3	629971.3878	3296735.1875	35373.5640	16707.95654	1.9240
4	110.4984	1.2961	108.6119	72.13879	26.1544	4	111.1419	1.4424	109.4023	70.93614	25.6718
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	13704.599	6	0.0000000	0.0000000	0.0000000	0.0000000	15371.981
7	0.0000	0.0000	333.3624	0.0001	5.8964	7	0.0000	0.0000	340.0503	0.0001	6.3166
8	0.0000000	48.871	9089.92.595	1094894.313	-2493.831	8	0.0000000	56.066	10711.40.375	1225826.938	-2422.209
9	4381.0960	3668.7875	13.3659			9	4923.6359	3800.0245	13.2578		
10	3476.9581.7	3144.70.0	-1681842.7	14885.758	-2101.312	10	4024714.1	230749.8	-1723886.6	16470.034	-2719.399
11	-2467.247	-93206.532	-3251601.031	4194.101	-786.4493	11	-260.692	-12389.694	-377088.125	3539.103	-971.666
12	-1419.0.217	36.204	-1839469.500	5997016.9	9440336.9	12	-151180.671	47.864	-1883869.750	5523167.7	9283247.1
13	-6705.935	-12797.437	-4162.672			13	-71.30.237	-14313.442	-4624.307		
14	2154.0977	0.0000	0.000	0.000		14	2181.2533	0.0000	0.000	0.000	
15	29.9256.1	105.95198	8.38975	2913076.0	105.86112	15	3401928.9	106.07097	6.12520	3405761.9	105.99264
16	6.36668	2060497.0	93.71716	14.56776	3427626.6	16	6.10453	2554040.8	96.55703	10.91618	3254544.8
17	279.39646	5.78618	4952473.8	314.24963	0.44907	17	221.16579	6.80896	4496561.6	316.44662	1.97753
1	490.0000	3458719.0	352752.0	65602.2	15487.256	1	495.0000	3536797.7	342126.1	68026.1	15744.318
2	-2026.352	480.361	51.133	-15.498	1.803	2	-2066.341	489.140	51.404	-15.797	1.752
3	632055.0781	3371968.2500	35634.5381	16961.95947	1.9634	3	634263.4844	3448430.4688	35899.9116	17229.36841	1.6183
4	111.2570	1.4094	109.5136	70.72329	25.5969	4	111.3529	1.3418	109.6295	70.50714	25.3203
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	13933.242	6	0.0000000	0.0000000	0.0000000	0.0000000	15634.537
7	0.0000	0.0000	336.2490	0.0001	5.7822	7	0.0000	0.0000	341.1688	0.0001	6.4167
8	0.0000000	49.734	9300.23.016	1113788.125	-2826.642	8	0.0000000	57.161	10959.69.438	1244669.156	-2356.708
9	4454.5064	3687.8718	13.4913			9	5004.2492	3816.7544	13.4472		
10	3551513.0	323835.9	-1654944.8	15099.272	-2195.578	10	4107726.7	236418.6	-1736891.2	16726.985	-2813.517
11	-265.477	-97200.689	-3328677.750	4339.638	-811.296	11	-260.923	-128825.492	-3847141.813	3755.987	-1005.352
12	-14209.695	37.132	-1843059.000	5932518.0	9419295.5	12	-15335.677	43.872	-1867456.500	5651012.4	9258872.6
13	-6759.154	-13002.759	-4254.076			13	-7197.998	-14549.947	-4925.835		
14	2156.5911	0.0000	0.000	0.000		14	2184.7924	0.0000	0.000	0.000	
15	2976107.1	105.97200	8.05010	2979924.6	105.88110	15	3677279.5	106.08661	5.82236	3681113.8	106.00947
16	8.02776	2144163.6	94.18170	13.99568	3400101.3	16	5.80421	2627179.3	96.89625	10.45570	3239142.3
17	228.29456	5.93669	4889810.2	314.52425	0.64757	17	219.84269	6.94647	4425423.6	316.82160	2.22737
1	500.0000	3616160.2	331105.0	70493.4	16000.021	1	505.0000	3696787.5	319677.6	71003.6	16249.109
2	-2244.482	497.795	50.725	-16.716	1.704	2	-2327.165	506.303	49.176	-16.867	1.701
3	636545.4609	3526189.4688	36164.3481	17493.85132	1.6730	3	638962.4609	3605208.0625	36422.9092	17752.47168	1.7246
4	111.4495	1.5967	109.7434	70.28765	25.4424	4	111.5474	1.6444	109.8573	70.06491	25.1627
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	14390.593	6	0.0000000	0.0000000	0.0000000	0.0000000	16164.547
7	0.0000	0.0000	336.0556	0.0001	5.9574	7	0.0000	0.0000	343.5815	0.0001	6.6382
8	0.0000000	51.608	9759.11.539	1150355.188	-2691.624	8	0.0000000	56.761	11469.11.906	1282996.891	-2230.933
9	4604.1138	3725.9574	13.5613			9	5160.0266	3848.3220	12.1736		
10	3704690.2	3010557.5	-1671643.8	15338.833	-2365.041	10	4277522.0	2073211.2	-1763002.6	17231.406	-3007.524
11	-263.767	-105569.221	-3473075.875	4720.346	-862.567	11	-261.459	-139127.609	-4001986.344	4204.888	-1059.471
12	-14589.311	39.015	-1849871.4.500	5800398.2	9375933.6	12	-15033.252	45.874	-1876717.8.750	5303108.4	9208581.9
13	-6873.195	-13422.818	-4439.084			13	-7332.599	-15030.736	-5132.727		
14	2167.7415	0.0000	0.000	0.000		14	2192.4021	0.0000	0.000	0.000	
15	3113228.9	106.00500	7.38709	3117055.1	105.91982	15	3831970.9	106.11678	5.23056	3835807.4	106.04310
16	7.36609	2275412.4	95.04687	12.90454	3347702.6	16	5.21338	2777767.2	97.53208	9.57299	3197602.0
17	226.06807	6.21415	4761748.7	315.10939	1.06228	17	217.07699	7.21044	4284327.6	317.62847	2.75628
1	510.0000	3778844.9	307830.0	75556.3	16492.906	1	515.0000	3861711.2	295560.0	78150.5	16732.809
2	-2411.960	514.758	48.405	-16.910	1.661	2	-2495.731	522.888	47.708	-16.435	1.576
3	641487.9688	3685455.1250	36676.2866	18005.91455	1.7746	3	644132.3203	3766910.0313	36923.9834	18255.69287	1.8346
4	111.6667	1.6927	109.9716	69.83001	25.2415	4	111.7662	1.7502	110.0853	69.61002	25.1986
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	14870.140	6	0.0000000	0.0000000	0.0000000	0.0000000	16676.284
7	0.0000	0.0000	344.7182	0.0001	6.1269	7	0.0000	0.0000	346.7182	0.0001	6.8707
8	0.0000000	54.526	11995.49.047	1321624.500	-2115.773	8	0.0000000	54.526	11995.49.047	1321624.500	-2115.773
9	5346.2695	3876.7608	11.2532			9	5346.2695	3876.7608	11.2532		
10	4452276.2	176235.0	-1769722.0	17715.118	-3211.175	10	4452276.2	176235.0	-1769722.0	17715.118	-3211.175
11	-262.444	-150022.838	-4159803.500	4673.571	-1120.979	11	-262.444	-150022.838	-4159803.500	4673.571	-1120.979
12	-15930.207	47.909	-18821099.000	5150444.2	9136221.1	12	-15930.207	47.909	-18821099.000	5150444.2	9136221.1
13	-7648.015	-15499.461	-5539.179			13	-7648.015	-15499.461	-5539.179		
14	2200.7384	0.0000	0.000	0.000		14	2200.7384	0.0000	0.000	0.000	
15	3759315.6	106.14551	4.65542	3763755.0	106.07673	15	3759315.6	106.14551	4.65542	3763755.0	106.07673
16	4.64009	2936001.6	98.11750	8.73817	3187560.8	16	4.64009	2936001.6	98.11750	8.73817	3187560.8
17	214.15645	7.45462	4139691.4	318.52102	3.32732	17	214.15645	7.45462	4139691.4	318.52102	3.32732
1	480.0000	3306365.0	372852.8	60886.8	14987.380	1	515.0000	3861711.2	295560.0	78150.5	16732.809
2	-1935.429	462.575	48.754	-14.608	1.794	2	-2495.731	522.888	47.708	-16.435	1.576
3	627989.0625	3222764.7500	35118.9092	16448.29321	1.4667	3	644132.3203	3766910.0313	36923.9834	18255.69287	1.8346
4	111.0459	1.3982	109.2881	71.14573	25.7451	4	111.7662	1.7502	110.0853	69.61002	25.1986
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	15118.908	6	0.0000000	0.0000000	0.0000000	0.0000000	16925.984
7	0.0000	0.0000	338.9839	0.0001	6.2386	7	0.0000	0.0000	347.6592	0.0001	6.9218
8	0.0000000	54.872	10467.29.656	1206670.469	-2488.879	8	0.0000000	54.029	12206.84.313	1361043.281	-2058.918
9	4840.9569	3782.4115	13.4103			9	5427.6347	3890.8360	10.6714		
10	3942934.0	263616.9	-1710.80.9	16234.885	-2624.039	10	4561442.9	1599235.5	-1802136.3	17930.599	-3313.160
11	-263.772	-119107.890	-3689275.813	5327.139	-963.153	11	-261.323	-155706.125	-4233882.5.938	6915.686	-1152.641
12	-15037.526	41.904	-1880321.2.000	5594157.1	9507119.0	12	-16078.436	48.939	-1885867.6.250	5072370.9	9129270.8
13	-7063.453	-14082.908	-4734.983			13	-7501.716	-15218.766	-5440.435		
14	2177.8732	0.0000	0.000	0.000		14	2205.1816	0.0000	0.000	0.000	
15	3327878.3	106.05498	6.43287	3331709.8	105.97501	15	3873793.3	106.15935	4.37576	3877632.5	106.08995
16	6.41366	2462317.4	96.20467	11.39082	3276220.9	16	6.33983	3014160.6	98.39268	8.33756	3153291.0
17	222.44930	6.66850	4582755.2	316.08905	1.73663	17	212.64145	7.56724	4066175.2	319.00228	3.62981

TABLE AP 7-1 (Sheet 9 of 10)
OBSERVED TRAJECTORY TABULATION

1	520.0000	3945971.6	282880.8	80784.8	16971.050	
2	-2575.044	530.474	47.601	-15.247	1.658	
3	646919.2949	3849559.7188	17173.5039	18503.29316	1.9165	
4	111.6448	1.8281	110.1992	69.37891	25.1162	
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
6	0.0000000	0.0000000	0.0000000	0.0000000	17171.109	
7	0.0000	0.0000	349.1553	0.0001	7.0123	
8	0.0000000	54.276	1253825.297	1360535.141	-2007.236	
9	5508.6938	3906.2061	10.0401			
10	4631780.9	143111.1	-1815555.8	18194.273	-3410.856	
11	-2844.355	-1615950.286	-4370547.063	7162.976	-1184.925	
12	-18276.493	49.917	-18896121.000	4991160.8	9101019.5	
13	-7557.791	-15955.069	-5539.547			
14	2209.8525	0.0000	0.000	0.000		
15	3956922.8	106.17284	4.09957	3960762.6	106.10479	
16	4.68403	3095656.9	98.05688	7.96795	3145023.6	
17	211.09209	7.67289	3991926.7	319.50909	3.94469	

1	555.0000	4570090.5	183448.5	100417.8	18729.982	
2	-3119.753	592.103	53.400	-14.497	1.845	
3	672619.9922	4461974.4375	18997.7605	20327.55518	2.7694	
4	112.5811	2.4346	111.0711	67.66878	24.6771	
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
6	0.0000000	0.0000000	0.0000000	0.0000000	18997.260	
7	0.000	0.0000	362.9514	0.0001	7.6496	
8	0.0000000	60.787	1456811.594	1499204.703	-1731.587	
9	6108.8132	4012.3598	5.5617			
10	52977.68.4	12065.7	-190933.1	19989.269	-4093.515	
11	-271.567	-207197.770	-4904591.438	9042.760	-1429.409	
12	-17297.426	57.478	-19160776.250	4486395.9	8895749.1	
13	-8001.695	-17609.625	-6251.687			
14	2252.3489	0.0000	0.000	0.000		
15	4574472.9	106.25875	2.29812	4578713.2	106.19914	
16	2.28479	3704740.7	100.23419	5.51066	3139651.4	
17	199.44335	8.18775	3655298.5	323.95700	6.59410	

1	525.0000	4031423.2	264820.2	83460.3	17709.507	
2	-2668.155	519.242	47.740	-13.947	1.666	
3	649891.3047	3933383.5313	17470.4082	18750.24414	2.0760	
4	111.9448	1.9318	110.3140	69.14300	25.0282	
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
6	0.0000000	0.0000000	0.0000000	0.0000000	17420.407	
7	0.0000	0.0000	350.7491	0.0001	7.1015	
8	0.0000000	54.812	1281572.156	1380108.172	-1958.600	
9	5590.0570	3973.3228	9.4127			
10	4723787.4	125825.1	-182880.1	18418.287	-3507.575	
11	-265.367	-1675596.894	-4402088.938	7415.476	-1217.835	
12	-16374.370	51.024	-18934060.500	4912823.0	9073880.0	
13	-7618.689	-16170.290	-5835.701			
14	2214.4141	0.0000	0.000	0.000		
15	4041304.2	106.18599	3.82823	4045144.7	106.11926	
16	3.81305	3178687.2	98.91066	7.56968	3136888.3	
17	204.51016	7.77147	3917001.2	320.04323	6.27315	

1	560.0000	4664413.9	167670.5	103402.3	19000.110	
2	-3191.411	601.564	54.605	-14.268	1.874	
3	677402.1953	4554560.3125	19275.6621	20606.02026	2.9404	
4	112.6893	2.4012	111.1412	67.41196	24.3790	
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
6	0.0000000	0.0000000	0.0000000	0.0000000	19275.661	
7	0.0000	0.0000	365.5031	0.0001	7.7420	
8	0.0000000	62.095	1487665.609	1519106.719	-1707.698	
9	6201.0543	4028.6304	4.8030			
10	5391.8.8	-8636.1	-192296.5	20174.418	-4186.465	
11	-272.932	-2144332.225	-4999232.336	9332.618	-1466.288	
12	-17403.823	58.583	-19208475.500	4317722.5	8884232.5	
13	-8079.127	-17859.099	-6355.192			
14	2260.0963	0.0000	0.000	0.000		
15	4668571.5	106.26994	2.05920	4672413.9	106.21146	
16	2.04513	3796850.7	100.43924	5.19885	3149499.0	
17	197.69195	8.22359	3378736.3	326.75615	7.05183	

1	530.0000	4118069.7	256408.8	86177.1	17449.428	
2	-2716.069	547.518	48.396	-13.426	1.641	
3	653093.1328	4018389.8438	17668.0313	18997.91772	2.1595	
4	112.0516	2.0579	110.4291	68.90503	24.9405	
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
6	0.0000000	0.0000000	0.0000000	0.0000000	17668.030	
7	0.0000	0.0000	352.4644	0.0001	7.1899	
8	0.0000000	55.668	1309727.141	1399770.828	-1913.242	
9	5672.0920	3941.9846	8.7319			
10	4815966.9	108094.2	-184209.9	18853.855	-3589.367	
11	-266.545	-1737?4.654	-4484329.875	7673.229	-1251.377	
12	-16522.060	52.079	-18972317.500	4831367.8	9045466.1	
13	-7684.236	-16402.556	-5729.714			
14	2230.1523	0.0000	0.000	0.000		
15	4129944.1	106.19883	3.56209	4130785.1	106.13337	
16	3.54727	3262054.5	99.15456	7.20225	3131013.8	
17	207.89761	7.86294	3841451.7	320.60670	6.61659	

1	570.0000	4857189.2	135055.2	109513.8	19559.144	
2	-3330.534	620.964	57.229	-13.584	1.988	
3	688089.0469	4743667.5625	19850.3943	21180.85864	3.1101	
4	112.9092	2.1714	111.3848	66.88950	24.1774	
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
6	0.0000000	0.0000000	0.0000000	0.0000000	19850.193	
7	0.0000	0.0000	371.2297	0.0001	7.9279	
8	0.0000000	65.010	1550643.094	1559758.141	-1667.194	
9	6391.8569	4061.8502	3.3112			
10	5802466.0	-51418.3	-195037.4	20721.408	-4369.583	
11	-275.593	-229480.799	-5166735.250	9929.384	-1543.290	
12	-17695.863	60.816	-19290090.750	4136583.7	8798431.0	
13	-8246.740	-18371.666	-6565.215			
14	2277.3473	0.0000	0.000	0.000		
15	4860100.0	106.29161	1.59210	4864142.3	106.23522	
16	1.57970	3986539.3	100.80943	4.60122	3178409.8	
17	196.15297	8.26650	3218873.8	326.91568	8.04549	

1	540.0000	4295035.1	226499.7	91738.8	17949.877	
2	-2874.499	565.236	52.165	-13.640	1.811	
3	660711.2891	4192019.8438	18187.3674	19517.40063	2.3144	
4	112.2611	2.2718	110.6642	68.42003	24.7604	
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
6	0.0000000	0.0000000	0.0000000	0.0000000	18187.366	
7	0.0000	0.0000	356.2940	0.0001	7.3729	
8	0.0000000	58.884	1367291.438	1459351.953	-1832.212	
9	5842.7010	3971.5315	7.5691			
10	5004927.9	71258.8	-186885.3	19144.822	-3784.889	
11	-268.226	-1665?6.295	-4451024.875	8204.667	-1329.385	
12	-16810.691	54.216	-19044787.000	4665024.3	8987176.5	
13	-7808.074	-16874.483	-5934.207			
14	2231.9844	0.0000	0.000	0.000		
15	4307086.9	106.22361	3.04461	4309928.7	106.16060	
16	3.03541	3435069.4	99.61486	6.49939	3176504.5	
17	204.58797	8.02219	3688598.2	321.83131	5.35269	

1	575.0000	4955706.8	118234.0	112441.6	19849.842	
2	-3197.461	631.017	58.671	-11.347	2.021	
3	696078.3125	4840278.5000	20147.4609	21477.98926	3.3443	
4	113.0205	2.3752	111.5079	66.62174	24.0736	
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
6	0.0000000	0.0000000	0.0000000	0.0000000	20147.459	
7	0.0000	0.0000	374.4412	0.0001	8.0213	
8	0.0000000	66.574	1582848.594	1580109.574	-1652.594	
9	6490.6649	4078.7808	2.5441			
10	5706790.3	-73491.6	-196419.0	21008.045	-4459.857	
11	-276.991	-237295.749	-5255578.113	10239.293	-1582.827	
12	-17841.484	62.965	-19331349.000	4044069.1	8766541.0	
13	-8337.412	-18635.401	-6671.776			
14	2286.9391	0.0000	0.000	0.000		
15	4958396.4	106.30711	1.36039	4962734.6	106.24673	
16	1.35397	4083719.0	100.98525	4.31506	3198279.9	
17	192.37199	8.27371	3139765.5	327.48678	8.58996	

1	545.0000	4385426.1	213901.7	94586.9	18705.211	
2	-2965.096	574.008	51.710	-13.855	1.760	
3	664115.5234	4280727.5625	18454.0173	19784.16455	2.4751	
4	112.3664	2.3596	110.7822	68.17279	24.6677	
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
6	0.0000000	0.0000000	0.0000000	0.0000000	18454.017	
7	0.0000	0.0000	358.3804	0.0001	7.4669	
8	0.0000000	57.840	1396723.484	1490237.734	-1795.983	
9	5974.7062	3982.8485	6.9120			
10	5101281.6	52049.1	-188229.1	19194.582	-3887.502	
11	-269.307	-1693276.637	-4713546.938	8478.434	-1355.884	
12	-16963.978	55.296	-19088978.250	4580039.1	8957233.3	
13	-7863.336	-17119.108	-6042.956			
14	2238.3664	0.0000	0.000	0.000		
15	4391658.1	106.23559	2.79177	4395500.1	106.17376	
16	2.77788	3523375.2	99.83258	6.16125	3178077.4	
17	202.89437	8.08742	3811308.0	322.49825	5.76674	

1	580.0000	5055642.5	1010069.6	119878.1	20145.639	
2	-3461.320	661.765	60.019	-13.075	2.067	
3	700536.1047	4938248.0625	20451.4316	21781.96289	3.7723	
4	113.1340	2.5924	111.6130	66.35169	23.9680	
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
6	0.0000000	0.0000000	0.0000000	0.0000000	20451.451	
7	0.0000	0.0000	377.9104	0.0001	8.1150	
8	0.0000000	68.045	1615539.297	1600543.766	-1660.132	
9	6591.9088	4098.0356	1.8966			
10	5812509.1	-98021.0	-197802.5	21299.975	-4568.185	
11	-277.969	-245310.209	-5367148.938	10548.845	-1621.062	
12	-17986.823	63.081	-19373441.000	3950257.5	8732917.0	
13	-8433.359	-18904.186	-6779.692			
14	2297.1988	0.0000	0.000	0.000		
15	5057976.8	106.31245	1.14497	5061320.8	106.24809	
16	1.13279	4182409.7	101.15530	4.03695	3221064.4	
17	190.58866	8.27128	3860716.3	328.52565	9.15423	

1	550.0000	4477102.7	198865.7	97479.4	18465.799	
2	-3046.852	583.098	52.352	-14.903	1.842	
3	668725.2422	4370708.6875	18724.5574	20054.78979	2.6027	
4	112.4734	2.4801	110.9014	67.92237	24.5733	
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
6	0.0000000	0.0000000	0.0000000	0.0000000	18724.556	
7	0.0000	0.0000	360.5856	0.0001	7.5776	
8	0.0000000	59.559	1426593.781	1479182.938	-1769.154	
9	6018.5742	3996.2383	5.7612			
10	5198891.6	32299.5	-187578.6	19650.023	-3999.772	
11	-270.348	-2001?6.025	-4870663.063	8757.621	-1392.003	
12	-17110.791	56.382	-19128451.500	4493827.1	8926750.8	
13	-7928.157	-17364.589	-6148.988			
14	2245.1333	0.0000	0.000	0.000		
15	4482576.6	106.24729	2.56270	4486419.1	106.18661	
16	2.52910	3613089.7	100.04202	5.83147	3132351.3	
17	201.17692	8.14239	3533519.1	323.20565	6.15975	

1	585.0000	5137128.4	835?2.2	119080.7	20450.263	
2	-3527.362	651.575	61.516	-12.631	2.192	
3	707526.6172	5037681.8750	20762.4688	22093.04614	4.0128	
4	113.2452	2.8217	111.7559	66.07804	23.8602	
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
6	0.0000000	0.0000000	0.0000000	0.0000000	20762.467	
7	0.0000	0.0000	381.6654	0.0001	8.2067	
8	0.0000000	69.718	1648756.719	1621067.297	-1633.599	
9	6695.6191	4113.4624	0.8692			
10	5919752.9	-114983.1	-199198.6	21599.292	-4636.256	
11	-280.195	-2533527.559	-5437445.563	10867.110	-1664.002	
12	-18131.806	64.228	-19415855.750	3855053.7	8698749.5	
13	-8533.796	-19179.024	-6887.826			
14	2308.2393	0.0000	0.000	0.000		
15	5159179.5	106.32253	0.92837	5163021.3	106.24909	
16	0.91640	4282762.1	101.31986	3.76699	3247285.0	
17	188.80488	8.26017	2981803.2	329.64039	9.76610	

TABLE AP 7-1 (Sheet 10 of 10)
OBSERVED TRAJECTORY TABULATION

583.471 S-IVB ENGINE CUTOFF COMMAND

1	588.4710	5228688.1	71771.4	121356.2	20661.275
2	-3571.352	659.373	67.558	-12.274	2.298
3	712709.7109	5107567.2500	20979.9071	22310.58375	4.1846
4	111.1254	3.9858	111.8440	65.88598	23.7842
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	20919.996
7	0.0000	0.0000	384.4794	0.0001	8.2727
8	0.0000000	70.886	1672125.422	1635366.328	-1631.102
9	6768.2511	4125.5813	0.4191		
10	5995094.7	-135180.0	-200172.1	21809.748	-4697.007
11	-280.873	-2549153.237	-55005555.250	11091.423	-1692.840
12	-18232.174	65.025	-19445604.250	3788143.8	8674708.0
13	-8624.921	-19370.652	-6983.690		
14	2317.3669	0.0000	0.000	0.000	
15	5713161.1	106.32941	0.78078	5234222.7	106.27662
16	0.76893	4353398.9	101.43097	3.58422	3263726.6
17	187.56851	8.24734	2927198.7	330.46255	10.21020

1	590.0000	5260104.1	65788.1	122346.1	20673.393
2	-3607.579	661.352	-8.726	-26.739	0.994
3	715055.3906	5136525.7500	20996.2180	22326.91994	4.1769
4	111.3661	3.9785	111.8809	65.80698	23.7504
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	20998.217
7	0.0000	0.0000	385.4870	0.0001	8.2691
8	0.0000000	-0.275	1682483.266	1641676.016	-1630.733
9	6774.5840	4126.6982	0.3468		
10	6028460.7	-142390.3	-200601.5	21816.713	-4737.564
11	-280.756	-2619351.385	-55284466.625	11191.117	-1705.652
12	-18276.601	65.378	-19458750.750	3758498.8	8664042.4
13	-8576.019	-19393.745	-6985.169		
14	2320.0311	0.0000	0.000	0.000	
15	5741937.7	106.33241	0.71636	5265779.2	106.27991
16	0.70457	4384712.8	101.47909	3.50477	3276964.6
17	187.02565	8.24005	2903241.7	330.83747	10.41113

1	595.0000	5363388.6	67419.6	125666.3	20639.764
2	-3740.125	666.732	-8.923	-26.509	1.115
3	722614.0938	5234722.3750	20986.4939	22317.75391	4.0819
4	111.4226	3.8891	111.9998	65.52344	23.6397
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	20996.493
7	0.0000	0.0000	389.7781	0.0001	8.2335
8	0.0000000	0.093	1716357.453	1662309.766	-1629.219
9	6774.9307	4126.7505	0.2473		
10	6137442.4	-166438.2	-202003.1	21775.487	-4881.910
11	-279.922	-2705B5.746	-56202710.625	11520.906	-1744.016
12	-18421.019	66.539	-19501305.500	3861463.1	8628966.0
13	-8443.242	-19420.519	-7045.378		
14	2331.7799	0.0000	0.000	0.000	
15	5363069.8	106.34221	0.50641	5368910.9	106.29061
16	0.49480	4487079.6	101.63194	3.24719	3309706.0
17	185.27305	8.20407	2825870.2	332.11088	11.08011

556.97 LAUNCH VEHICLE/SPACECRAFT SEPARATION COMMAND

1	596.9700	5404035.1	40000.0	124982.2	20625.999
2	-3792.348	668.910	-7.053	-26.510	1.115
3	725543.6078	5279573.8750	20982.4021	22313.86890	4.0441
4	111.4433	3.8835	112.0467	65.41479	23.5959
5	-0.0000000	-0.0000000	-0.0000000	-0.0000000	-0.0000000
6	-0.0000000	-0.0000000	-0.0000000	-0.0000000	20982.401
7	-0.0000	-0.0000	391.1634	0.0001	8.2197
8	0.0000000	-0.013	1729704.094	1670439.281	-1628.696
9	6774.4598	4126.7536	0.2390		
10	6180324.0	-176111.6	-202556.0	21758.695	-4938.612
11	-279.490	-2740A5.430	-56565555.625	11652.439	-1766.901
12	-18477.831	66.998	-19517885.250	3823193.4	8615062.5
13	-8389.881	-19430.525	-7049.099		
14	2336.3061	0.000C	-0.000	-0.000	
15	5405674.6	106.34607	0.42396	5409515.6	106.29481
16	0.41242	4527374.3	101.69036	3.14661	3323181.3
17	184.59240	8.18491	2795814.3	332.63332	11.34865

600.00 FIRST MOTION BETWEEN LAUNCH VEHICLE AND SPACECRAFT

1	600.0000	5466500.4	20387.8	129018.7	20604.961
2	-3872.605	672.310	-7.119	-26.476	1.115
3	729994.1250	5340847.3125	20976.1052	22307.84403	3.9838
4	111.6210	3.7986	112.1185	65.24692	23.5265
5	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6	0.0000000	0.0000000	0.0000000	0.0000000	20976.104
7	0.0000	0.0000	393.7727	0.0001	8.1988
8	0.0000000	0.013	1750232.500	1682943.347	-1626.604
9	6774.9785	4126.7555	0.2321		
10	6246216.1	-191207.4	-203395.3	21732.567	-5025.891
11	-278.804	-2794A2.707	-57126775.875	11856.516	-1791.093
12	-18565.116	67.707	-19563185.000	3864297.6	8593384.9
13	-8307.715	-19445.757	-7105.364		
14	2343.1590	0.0000	0.000	0.000	
15	5468098.1	106.35702	0.29745	5471936.9	106.30129
16	0.28600	4589381.3	101.77836	2.99285	3345254.6
17	183.55684	8.15010	2750083.0	333.46083	11.76712

1. METEOROLOGICAL DATA

A summary of the meteorological data during the AS-202 launch and flight is presented in this appendix. Surface measurements at the Kennedy Space Center at approximately the time of launch are recorded as follows:

TIME (GMT)	CLOUDS			VISIB (mi)	PRESS. @ MSL* (mbars)	DRY BULB TEMP (deg F)	RELATIVE HUMIDITY (%)	WIND DIRECTION (deg)	WIND SPEED (kt)
	AMOUNT (%)	TYPE	BASE (ft)						
1700	7	Cumulus	2,500	10	1,017.3	87	70	140	10
	1	Cirrus	UNK						
1716	8	Cumulus	2,500	10	1,017.3	86	70	170	10
	1	Cirrus	UNK						
1731	8	Cumulus	2,700	10	1,017.3	87	68	150	10
	1	Cirrus	UNK						

* MSL = Mean sea level.

Table AP 8-1 presents definitions, units, and sign conventions for the meteorological data presented in table AP 8-2. Table AP 8-2 records the meteorological data to an altitude of 250,000 feet.

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TABLE AP 8-1 (Sheet 1 of 2)
METEOROLOGICAL DATA (AA99)

	A	B	C	D	E	F
1	ALT.	TEMP.	PRESS	WIND VEL	WIND DIR	RPL WIND
2	VAP. PRESS	DENSITY	PRESS	VEL/SOUND	DPT./FREE	ELEC/PERT
3	WIND PITCH	WIND YAW	WD. SIGNAL	WD. NOISE	DENSITY	VISC.
4	TEMP.	PITCH SHEAR	YAW SHEAR			
1	0.0	565.13	2121.210	16.4342	170.900	0.6907
2	60.0960	0.0022	2123.210	11553.769	1.3004	1.3234
3	-6.9327	-14.4473	-2.4645	16.1550	7.2220	0.030291
4	29.700	-0.004452	-0.01817616			
1	5000.0	574.22	1785.344	36.4742	274.864	0.9125
2	55.2128	0.0020	1785.344	11125.632	1.3001	1.3001
3	18.1417	-31.5125	25.6815	25.7429	6.3357	0.030291
4	18.985	-0.004416	-0.00938173			
1	10000.0	509.58	1490.613	42.6509	226.003	0.4562
2	11.6644	0.0017	1490.613	11084.273	1.2702	1.2702
3	21.9469	-36.3589	30.6806	29.6278	5.4684	0.030301
4	9.950	-0.000425	-0.00038315			
1	15000.0	496.83	1237.522	46.8768	223.712	0.2992
2	4.0436	0.0015	1237.522	10911.164	1.2002	1.2002
3	22.5089	-41.1172	32.1839	33.4905	4.6817	0.030301
4	1.754	0.000293	-0.00115147			
1	20000.0	479.00	1021.107	42.6509	211.768	0.1493
2	1.3575	0.0012	1021.107	10731.178	1.2001	1.2001
3	12.3029	-40.8315	22.4517	36.2960	3.9935	0.030291
4	-1.038	-0.007787	0.00484669			
1	25000.0	461.10	836.703	42.5197	211.320	0.2759
2	0.9324	0.0011	836.703	10552.889	1.2001	1.2001
3	11.1953	-40.5352	21.4943	36.2946	3.3997	0.030301
4	-16.984	-0.004015	-0.00491768			
1	30000.0	441.54	680.308	44.5407	194.247	0.3315
2	0.4310	0.0009	680.308	10333.218	1.2001	1.2001
3	-0.7297	-44.1712	10.7793	43.0481	2.4871	0.030291
4	-27.652	-0.009110	-0.00469575			
1	35000.0	420.07	547.299	41.5223	219.332	0.2197
2	0.0853	0.0008	547.299	10096.768	1.2001	1.2001
3	16.7506	-37.9361	25.9985	32.3081	2.4418	0.030291
4	-39.778	0.001765	0.00928955			
1	40000.0	398.31	435.626	40.9734	232.536	0.2202
2	0.0215	0.0006	435.626	9874.383	1.2001	1.2001
3	30.4275	-39.6356	39.6692	33.4099	2.7498	0.030301
4	-51.466	-0.001139	0.00299004			
1	45000.0	374.97	342.335	28.1890	225.912	0.2200
2	0.0000	0.0005	342.335	954.328	1.3001	1.3301
3	14.6081	-24.0809	20.3430	19.4795	1.5931	0.030301
4	-62.610	0.006757	-0.00644054			
1	50000.0	370.34	266.511	27.9659	189.320	0.0301
2	0.0000	0.0004	266.511	943.391	1.3001	1.3001
3	-2.2725	-22.8445	3.7176	22.6963	1.3490	0.030301
4	-67.408	-0.003903	0.00011464			
1	55000.0	371.20	207.133	15.8893	179.485	0.0301
2	0.0000	0.0003	207.133	944.490	1.3500	1.3500
3	-3.6393	-15.1961	-2.4152	19.6105	1.2459	0.030291
4	-66.978	0.004420	0.00736842			
1	60000.0	379.21	161.934	35.0919	117.696	0.0301
2	0.0000	0.0002	161.934	956.629	1.3001	1.3301
3	-16.2750	-7.7407	-11.0594	16.3351	0.7989	0.030291
4	-62.478	0.001642	-0.00209614			
1	65000.0	391.15	126.367	36.9029	94.224	0.0301
2	0.0000	0.0002	126.367	957.066	1.0000	1.0301
3	-16.0992	6.7359	-16.6087	2.8357	0.6214	0.030301
4	-61.400	-0.000940	-0.00666202			
1	70000.0	387.96	99.146	42.6509	112.932	0.0301
2	0.0000	0.0001	99.146	965.451	1.3300	1.3300
3	-42.3170	-5.2198	-39.5241	15.9944	0.6799	0.030301
4	-57.671	0.000055	-0.00033696			
1	75000.0	386.73	78.287	34.2520	83.365	0.0301
2	0.0000	0.0001	78.287	976.432	1.3000	1.3001
3	-31.0594	14.3374	-33.7080	-5.8111	0.3699	0.030301
4	-52.744	0.000515	-0.00699737			
1	80000.0	401.09	61.939	64.0965	92.464	0.0301
2	0.0000	0.0001	61.939	981.775	1.3000	1.3000
3	-62.5810	13.9252	-64.0334	2.7412	0.2899	0.030301
4	-50.325	-0.003432	0.00329205			
1	85000.0	405.73	49.146	63.5433	90.944	0.0301
2	0.0000	0.0001	49.146	987.438	1.3000	1.0303
3	-61.5246	15.2957	-63.3870	1.1492	3.2275	0.030291
4	-47.747	0.005839	0.01073931			
1	90000.0	410.87	39.245	62.3360	81.728	0.0301
2	0.0000	0.0001	39.245	991.475	1.3000	1.3301
3	-57.2626	26.6280	-61.6856	-4.9641	0.1758	0.030301
4	-44.890	-0.000445	0.00212445			
1	95000.0	418.76	31.303	63.6168	97.332	0.0301
2	0.0000	0.0000	31.303	1033.144	1.3000	1.3000
3	-65.0276	8.7320	-65.0716	8.3959	0.1401	0.030301
4	-40.518	0.001026	0.00272426			
1	100000.0	419.66	25.129	62.4934	97.400	0.0301
2	0.0000	0.0000	25.129	1004.267	1.3000	1.3000
3	-51.2148	11.4482	-52.4327	2.1973	0.1122	0.030301
4	-40.058	0.001293	0.00418370			
1	105000.0	427.27	20.245	75.4593	96.948	0.0301
2	0.0000	0.0000	20.245	1011.317	1.3000	1.3000
3	-71.7524	23.3580	-75.3330	-3.9912	0.7848	0.030301
4	-35.778	-0.007928	0.00111310			
1	110000.0	427.99	16.493	61.7336	96.224	0.0301
2	0.0000	0.0000	16.493	1014.168	1.3000	1.3000
3	-65.5083	9.3758	-60.8732	6.6044	0.4722	0.030301
4	-35.378	0.001698	-0.00161972			
1	115000.0	431.87	13.298	55.4068	92.624	0.0301
2	0.0000	0.0000	13.298	1021.109	1.3000	1.3000
3	-54.5706	7.6147	-55.3615	1.5923	0.3575	0.030301
4	-32.113	0.007327	0.00007358			
1	120000.0	436.40	10.763	76.4520	84.608	0.0300
2	0.0000	0.0000	10.763	1024.088	1.3000	1.3000
3	-69.7782	25.9651	-74.1208	-7.0204	3.3462	0.030301
4	-30.704	-0.008850	-0.00867743			
1	125000.0	448.58	8.726	99.0814	97.200	0.0300
2	0.0000	0.0000	8.726	1038.274	1.3000	1.3000
3	-98.1580	33.3904	-98.2790	12.4710	5.0364	0.030301
4	-23.940	-0.000017	-0.00468877			
1	130000.0	474.46	7.143	59.0814	97.648	0.0300
2	0.0000	0.0000	7.143	1067.802	1.3000	1.3000
3	-56.5430	7.8064	-58.5687	7.6116	0.3282	0.030301
4	-9.562	0.004802	-0.00681495			
1	135000.0	484.88	5.895	72.1785	84.816	0.0300
2	0.0000	0.0000	5.895	1079.668	1.3000	1.3000
3	-67.7360	24.9005	-71.4727	-6.5207	0.7228	0.030301
4	-3.774	-0.005722	0.00355075			
1	140000.0	476.10	4.865	64.4305	93.376	0.0300
2	0.0000	0.0000	4.865	1069.652	1.3000	1.3000
3	-65.0391	13.4793	-66.1117	5.8133	0.5192	0.030301
4	-8.650	0.011170	-0.00606037			
1	145000.0	472.77	4.005	57.2441	97.704	0.0300
2	0.0000	0.0000	4.005	1065.906	1.3000	1.3000
3	-8.3548	36.7651	-17.5452	-32.8670	3.9159	0.030301
4	-10.500	-0.006258	0.01108117			
1	150000.0	468.62	3.294	104.1995	82.160	0.0300
2	0.0000	0.0000	3.294	1061.220	1.3000	1.0000
3	-93.9912	40.3354	-103.1600	-14.1166	5.7112	0.030301
4	-12.804	-0.013556	-0.01039623			
1	155000.0	485.72	2.715	85.2251	78.168	0.0300
2	0.0000	0.0000	2.715	1065.407	1.3000	1.0000
3	-76.0302	34.4700	-93.3963	-17.4811	9.0105	0.030301
4	-3.305	0.001357	0.01299165			
1	160000.0	490.31	2.248	95.1444	94.144	0.0300
2	0.0000	0.0000	2.248	1065.496	1.3000	1.0000
3	-93.4378	17.9189	-96.8917	6.8752	3.3788	0.030301
4	-0.757	-0.000837	-0.00396262			
1	165000.0	495.51	1.865	97.8740	85.536	0.0300
2	0.0000	0.0000	1.865	1091.241	1.3000	1.3000
3	-92.1552	32.9473	-97.5405	-7.9737	0.7071	0.030301
4	2.134	-0.000839	-0.00412643			
1	170000.0	503.34	1.551	68.0315	116.640	0.0300
2	0.0000	0.0000	1.551	1099.830	1.3000	1.0000
3	-66.4634	-13.5723	-60.6860	30.3119	0.7058	0.030301
4	6.485	0.008572	-0.01189657			
1	175000.0	502.20	1.292	27.4278	245.040	0.0300
2	0.0000	0.0000	1.292	1098.577	1.3000	1.0000
3	20.9895	-17.3527	24.7655	11.5789	0.3044	0.030301
4	5.868	0.012954	0.00167828			
1	180000.0	497.89	1.075	47.7186	277.176	0.0300
2	0.0000	0.0000	1.075	1093.855	1.3000	1.0000
3	47.2517	-6.4353	47.3072	-6.0116	0.3040	0.030301
4	3.454	-0.004369	-0.00316407			

TABLE AP 8-1 (Sheet 2 of 2)
METEOROLOGICAL DATA (AA99)

	A	B	C	D	E	F
1	1950C3.0	486.31	0.492	39.3701	751.792	0.7707
2	0.0000	0.0000	0.492	1041.065	1.3000	1.0000
3	37.9206	-21.5492	37.3762	12.7944	0.3036	0.000091
4	-2.976	-0.001562	-0.00753090			

	A	B	C	D	E	F
1	190000.0	477.94	0.727	0.0000	0.000	0.0000
2	0.0000	0.0000	0.727	1071.715	1.3000	1.0000
3	0.0000	0.0000	0.0000	0.0000	0.3029	0.000091
4	-7.629	0.000000	0.00000000			

	A	B	C	D	E	F
1	1950C0.0	462.43	0.569	0.0000	0.000	0.0000
2	0.0000	0.0000	0.569	1054.187	1.0000	1.0000
3	0.0000	0.0000	0.0000	0.0000	0.3021	0.000091
4	-10.243	0.000000	0.00000000			

	A	B	C	D	E	F
1	200000.0	446.93	0.445	0.0000	0.000	0.0000
2	0.0000	0.0000	0.445	1035.162	1.3000	1.0000
3	0.0000	0.0000	0.0000	0.0000	0.3014	0.000091
4	-24.858	0.000000	0.00000000			

	A	B	C	D	E	F
1	205000.0	431.42	0.368	0.0000	0.000	0.0000
2	0.0000	0.0000	0.368	1018.226	1.3000	1.0000
3	0.0000	0.0000	0.0000	0.0000	0.3015	0.000091
4	-33.472	0.000000	0.00000000			

	A	B	C	D	E	F
1	210000.0	422.96	0.281	0.0000	0.000	0.0000
2	0.0000	0.0000	0.281	1000.192	1.3000	1.0000
3	0.0000	0.0000	0.0000	0.0000	0.3012	0.000091
4	-38.172	0.000000	0.00000000			

	A	B	C	D	E	F
1	215000.0	414.56	0.226	0.0000	0.000	0.0000
2	0.0000	0.0000	0.226	988.136	1.3000	1.0000
3	0.0000	0.0000	0.0000	0.0000	0.3010	0.000091
4	-42.837	0.000000	0.00000000			

	A	B	C	D	E	F
1	220000.0	406.22	0.180	0.0000	0.000	0.0000
2	0.0000	0.0000	0.180	988.043	1.3000	1.0000
3	0.0000	0.0000	0.0000	0.0000	0.3008	0.000091
4	-47.471	0.000000	0.00000000			

	A	B	C	D	E	F
1	225000.0	397.99	0.144	0.0000	0.000	0.0000
2	0.0000	0.0000	0.144	977.975	1.3000	1.0000
3	0.0000	0.0000	0.0000	0.0000	0.3007	0.000091
4	-52.046	0.000000	0.00000000			

	A	B	C	D	E	F
1	230000.0	389.89	0.114	0.0000	0.000	0.0000
2	0.0000	0.0000	0.114	967.977	1.3000	1.0000
3	0.0000	0.0000	0.0000	0.0000	0.3005	0.000091
4	-56.544	0.000000	0.00000000			

	A	B	C	D	E	F
1	235000.0	381.96	0.090	0.0000	0.000	0.0000
2	0.0000	0.0000	0.090	958.074	1.3000	1.0000
3	0.0000	0.0000	0.0000	0.0000	0.3004	0.000091
4	-60.952	0.000000	0.00000000			

	A	B	C	D	E	F
1	240000.0	374.18	0.071	0.0000	0.000	0.0000
2	0.0000	0.0000	0.071	948.243	1.3000	1.0000
3	0.0000	0.0000	0.0000	0.0000	0.3004	0.000091
4	-65.270	0.000000	0.00000000			

	A	B	C	D	E	F
1	245000.0	366.56	0.055	0.0000	0.000	0.0000
2	0.0000	0.0000	0.055	938.573	1.3000	1.0000
3	0.0000	0.0000	0.0000	0.0000	0.3003	0.000091
4	-69.504	0.000000	0.00000000			

	A	B	C	D	E	F
1	250000.0	359.06	0.043	0.0000	0.000	0.0000
2	0.0000	0.0000	0.043	928.917	1.3000	1.0000
3	0.0000	0.0000	0.0000	0.0000	0.3002	0.000091
4	-73.673	0.000000	0.00000000			

TABLE AP 8-2
METEOROLOGICAL DATA TABLE OF DEFINITIONS

Table of Definitions

Program Symbol	Definition
Alt.	Altitude: geocentric altitude (ft)
Density	Density: row 2, column B (slugs/ft^3) row 3, column E (pounds/ft^3)
Elec/Ref	Electromagnetic Index of Refraction: (unitless)
Opt./Ref	Optical Index of Refraction: (unitless)
Pit. Shear	Shear of Wind Velocity Pitch Component: (ft/sec/ft)
Press	Ambient Pressure: (lbf/ft^2)
Rel Humd	Relative Humidity: (decimal)
Temp.	Ambient Temperature: row 1, column B (deg R) row 4, column A (deg C)
Vap. Press	Water Vapor Pressure: (lbf/ft^2)
Vel/Sound	Velocity of Sound: (ft/sec)
Visc.	Coefficient of Viscosity: (slugs/ft-sec)
Wd. Merid.	Meridional Component of Wind Velocity: component of wind velocity vector measured along lines of longitude, positive north (ft/sec)
Wd. Zonal	Zonal Component of Wind Velocity: component of wind velocity vector measured along lines of latitude, positive east (ft/sec)
Wind Dir	Wind Direction: direction from which wind is blowing, measured clockwise from north (deg)
Wind Pitch	Wind Velocity Pitch Component: component of wind velocity vector along vehicle flight path, positive downrange (ft/sec)
Wind Vel	Magnitude of Wind Velocity: (ft/sec)
Wind Yaw	Wind Velocity Yaw Component: component of wind velocity vector perpendicular to pitch component, lying in the local tangent plane, and positive right looking downrange (ft/sec)
Yaw Shear	Shear of Wind Velocity Yaw Component: (1/sec)

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P. 482

1. GLOSSARY AND ABBREVIATIONS

This appendix (table AP 9-1) lists the commonly used S-IVB-202 stage flight evaluation terms and abbreviations together with their definitions.

TABLE AP 9-1 (Sheet 1 of 13)
GLOSSARY AND ABBREVIATIONS

Abbreviation	Terms	Definition
AACS	---	Auxiliary attitude control system
ac	---	Alternating current
---	Aerodynamically induced vibration	The oscillation of a mechanical system when set into motion by the turbulent boundary layer during flight. It is dependent on the shape and velocity of the body
amp	---	Ampere
APS	---	Auxiliary propulsion system
AS	---	Apollo Saturn
ASI	---	Augmented spark igniter
AST	---	All systems test
A_t	---	Throat area
aux	---	Auxiliary
---	Average mixture ratio	The time average of the propellant mixture ratio over 1-sec time intervals between 90 percent thrust buildup and Engine Cutoff Command
---	Average thrust or specific impulse	Determined between the time of 90 percent thrust and Engine Cutoff Command
A_W	---	Wind azimuth (deg)
A_{XM}	---	Axial acceleration (ft/sec^2)
Btu	---	British thermal unit
CDDT	---	Countdown demonstration test
C_F	---	Thrust coefficient
C_f	Collapse factor	A measure of the effectiveness of pressurization defined as: $C_f = \frac{M_{actual}}{M_{theoretical}}$, where M actual: is the mass necessary to pressurize the propellant tank (lbm)

TABLE AP 9-1 (Sheet 2 of 13)
GLOSSARY AND ABBREVIATIONS

Abbreviations	Terms	Definition
C_f (Cont)		$M_{theoretical}$: is the mass necessary to pressurize the propellant tank if heat and mass transfer across the ullage boundaries are neglected (lbm)
CM	---	Command module
---	Composite data (acoustic and vibration)	The total energy of the oscillatory phenomenon, consisting of all frequencies and amplitudes sensed by the transducers, and represents the phenomenon at the point of measurement within the limitations of the data acquisition and reduction systems
cont	---	Control
CPIF	---	Cost plus incentive fee
cpm	---	Cycles per minute
cps	---	cycles per second
CSM	---	Command service module
CVS	---	Continuous vent system
DAC	---	Douglas Aircraft Company, Inc.
DAC/FTC	---	Douglas Aircraft Company, Inc./ Florida Test Center
DAC/HB	---	Douglas Aircraft Company, Inc./ Huntington Beach
db	---	Decibel
dbm	---	10 log P (milliwatts) where p = power
dbw	---	10 log P (watts)
dc	---	Direct current
deg	---	Degree
---	Depletion Engine Cutoff Command	The time that engine cutoff was, or would be, initiated by the depletion level sensors

TABLE AP 9-1 (Sheet 3 of 13)
GLOSSARY AND ABBREVIATIONS

Abbreviations	Terms	Definition
DDAS	---	Digital data acquisition system
DEE	---	Digital events evaluation
D/O	---	Dropout
DRSCR	---	Digital range safety command receiver
e	---	Eccentricity
EBW	---	Exploding bridgewire
ECC	---	Engine Cutoff Command
ECF	---	End conditions of flight
ECP	---	Engineering change proposal
ECS	---	Environmental control system
EDS	---	Emergency detection system
---	Effective burntime	The engine burntime from 90 percent thrust buildup to Engine Cutoff Command
ELS	---	Earth landing system
EMC	---	Electromagnetic compatibility
EMR	Engine propellant mixture ratio	The ratio of engine LOX mass flowrate to LH2 mass flowrate includes gas generator operations
eng	---	Engine
---	Engine cutoff transient	Engine operation during the period from the Engine Cutoff Command until the end of thrust decay
EPS	---	Electrical power system
ESC	---	Engine Start Command
---	Engine start transient	Engine operation during the period from the Engine Start Command until the time of 90 percent thrust (approximately a 3-sec period)

TABLE AP 9-1 (Sheet 4 of 13)
GLOSSARY AND ABBREVIATIONS

Abbreviations	Terms	Definition
---	Engine steady-state operation	Engine operation during the period from the time of 90 percent thrust until Engine Cutoff Command
ETD	---	End of thrust decay
env	---	Environmental
ETR	---	Eastern Test Range
°F	---	degree Fahrenheit
F	Stage longitudinal thrust	Thrust (lbf) developed by the J-2 engine. Ullage rocket thrust is not included
F_a	---	Ullage rocket thrust (lbf)
---	Flow integral propellant mass history	That propellant mass history determined by combining independent engine analyses by a statistical method
FM	---	Frequency modulation
FPR	Flight performance reserve	Usable mass onboard at predicted guidance cutoff
fps	---	Feet per second
ft	---	Foot
FTC	---	Florida Test Center
g	Gravitational acceleration	The acceleration produced by the force of gravity, which varies with the altitude and elevation of the point of observation. The value 32.1739 ft/sec^2 has been chosen as the standard by international agreement for sea level at 45° north latitude
GCC	---	Guidance Cutoff Command
GH2	---	Gaseous hydrogen
GMT	---	Greenwich mean time
GN2	---	Gaseous nitrogen

TABLE AP 9-1 (Sheet 5 of 13)
GLOSSARY AND ABBREVIATIONS

Abbreviations	Terms	Definition
GOX	---	Gaseous oxygen
gpm	---	Gallons per minute
GSE	---	Ground support equipment
h	---	Altitude
h (AP)	---	Apogee altitude
He	---	Helium
HF	---	High frequency
hr	---	Hour
i	---	Inclination
IECO	---	S-IB stage Inboard Engine Cutoff Command
IGM	---	Iterative guidance mode
IMU	---	Inertial measurement unit
in./in.	---	Inches per inch (strain)
IPCL	---	Instrumentation Program and Components List
ips	---	Inches per second
I_{sp}	---	Specific impulse
I_t	---	Total impulse
IU	---	Instrument unit
k	---	Insulation thermal conductivity
kc	---	Kilocycles
KSC	---	Kennedy Space Center
ksi	---	1,000 lb/in.^{2}
lbf	---	Pounds force
lbm	Pounds mass	1/32.1739 slug

TABLE AP 9-1 (Sheet 6 of 13)
GLOSSARY AND ABBREVIATIONS

Abbreviations	Terms	Definition
LC	---	Launch Complex
L/C	---	Loading Computer
LEM	---	Lunar excursion module
LES	---	Launch escape system
LET	---	Launch escape tower
---	Level sensor residuals	Those propellant residuals above the main propellant valves determined by combining data from one or more level sensors by a statistical method and extrapolating to Engine Cutoff Command
LH2	---	Liquid hydrogen
LO	---	Vehicle liftoff time
---	Look angle	Angle between the vehicle centerline and the line of sight, measured from the rear of the vehicle (deg)
LOS	---	Loss of signal
LOX	---	Liquid oxygen
LV	---	Launch vehicle
LVDC	---	Launch vehicle digital computer
M	---	Mach number
$\dot{M}$	Stage propellant mass flowrate (lbm/sec)	Engine propellant mass flowrate (includes propellant flowrate for gas generator operation)
$\dot{M}_f$	Stage LH2 mass flowrate (lbm/sec)	Engine LH2 mass flowrate (includes LH2 flowrate for gas generator operation)
$\dot{M}_o$	Stage LOX mass flowrate (lbm/sec)	Engine LOX mass flowrate (includes LOX flowrate for gas generator operation)
ma	---	Milliampere
max q	---	Maximum dynamic pressure
µin./in.	Micro inch per inch	Millionth of an inch per inch

TABLE AP 9-1 (Sheet 7 of 13)
GLOSSARY AND ABBREVIATIONS

Abbreviations	Terms	Definition
MDF	---	Mild detonating fuse
MHz	---	Millihertz
Mod	---	Module
MOV	---	Main oxidizer valve
ms	Millisecond	Thousandth of a sec
MSC	---	Manned Spacecraft Center, Houston, Texas
MSFC	---	Marshall Space Flight Center
mvdc	---	Millivolt - direct current
mxr	---	Multiplexer
N/A	---	Not applicable
NASA	---	National Aeronautics and Space Administration
NC	---	Normally closed
---	Ninety percent thrust buildup	Time from Engine Start Command until the last engine chamber pressure (injector end) reaches 618 psia
nmi	---	Nautical miles
NO	---	Normally open
No.	---	Number
N_2O_4	NTO	Nitrogen Tetroxide
NPSH	---	Net positive suction head
NPV	---	Nonpropulsive vent
OAT	---	Overall test
OECO	---	S-IB stage Outboard Engine Cutoff Command
O-P	---	Zero to peak
oxid	---	Oxidizer

TABLE AP 9-1 (Sheet 8 of 13)
GLOSSARY AND ABBREVIATIONS

Abbreviations	Terms	Definition
P	---	Geodetic latitude
P	---	Pitch
P_a	---	Ambient pressure
P_c	---	Combustion chamber pressure measured at the injector
PA	---	Pressure actuated
PAM	---	Pulse amplitude modulation
PCF	---	Preconditions of flight
PCM	---	Pulse code modulation
PMR	Programmed mixture ratio	A method of controlling the PU valve mixture ratio to obtain maximum efficiency of the stage. The propellant loading is provided to cause the PU system to command the PU valve against the LOX rich stop for the initial portion of flight and then decrease to a lower mixture ratio during the final portion of flight
P/N	---	Part number
ppm	---	Parts per million
---	Propellant residuals	The sum of LOX and LH2 remaining on-board at Engine Cutoff Command. The residuals include both usable and trapped propellants
PS	---	Pressurization system
P/S	---	Pulse sensor
PSD	---	Power spectral density
psia	---	Pounds per square inch absolute

TABLE AP 9-1 (Sheet 9 of 13)
GLOSSARY AND ABBREVIATIONS

Abbreviations	Terms	Definition
psid	---	Pounds per square inch differential
psig	---	Pounds per square inch gauge
PTCS	---	Propellant tanking computer system
P/U	---	Pickup
PU	---	Propellant utilization
---	PU system propellant mass history	That propellant mass history determined for flight by the PU system
---	PU system residuals	Those propellant residuals above the main propellant valves determined by the PU system
q	---	Dynamic pressure
qty	---	Quantity
°R	---	Degrees Rankine
RACS	---	Remote analog calibration system
RCS	---	Reaction control system
reg	---	Regulator
RF	---	Radio frequency
RFI	---	Radio frequency interference
rms	---	Root mean square
RO	---	An event time used as reference for S-IVB stage flight evaluation sequence of events. Defined as the first Greenwich mean time second prior to vehicle liftoff
RP	---	Reference plane
rpm	---	Revolutions per minute
R/S	---	Range safety
RSCR	---	Range safety command receiver

TABLE AP 9-1 (Sheet 10 of 13)
GLOSSARY AND ABBREVIATIONS

Abbreviations	Terms	Definition
rss	---	Root sum square
S	---	Surface range (ft)
scfm	---	Standard cubic ft/min
scim	---	Standard cubic in./min
sco	---	Subcarrier oscillator
sec	---	seconds
S-IB	---	First stage of the Saturn IB (200) series of vehicles
S-IVB	---	Second stage of the Saturn IB (200) series of vehicles
SLA	---	Spacecraft LEM adapter
---	Slug	English system unit of mass
SM	---	Santa Monica
SM	---	Service module
SPS	---	Service propulsion system
SOV	---	Shutoff valve
SSB	---	Single sideband
SSS	---	Stage switch selector
sta	---	Station
---	Statistical weighted average loaded propellants	The most accurate determination of actual propellant load at liftoff as derived from the statistically weighted average mass
---	Statistical weighted average mass determina-	A statistical combination of the PU system, engine system, flight simulation, and propellant level sensors at Engine Start Command and Engine Cutoff Command

TABLE AP 9-1 (Sheet 11 of 13)
GLOSSARY AND ABBREVIATIONS

Abbreviations	Terms	Definition
---	Statistical weighted average residual propellants	The most accurate determination of actual propellant residual at Engine Cutoff Command as derived from the statistically weighted average mass determination method
STC	---	Sacramento Test Center
S/V	---	Space vehicle
Sw sel	---	Switch selector
T	---	Countdown time from prospective liftoff or as specifically defined in the text
Tel 2	---	Telemetry station at KSC
tk	---	Tank
T/M	---	Telemetry
---	Total depletion burntime	The engine burntime from Engine Start Command to the time that the Depletion Engine Cutoff Command would have been initiated
---	Total propellants consumed	That amount of liquid propellants consumed from Engine Start Command to Engine Cutoff Command includes engine consumption, boiloff, and LH2 tank pressurant
---	Total stage burntime	The engine burntime from Engine Start Command to Engine Cutoff Command
---	Total stage mass history	A compilation of all final hardware, propellant, and gas masses. The measured and computed mass of each constituent is adjusted within its accuracy band so that the total stage mass at Engine Start Command and Engine Cutoff Command agrees with the total stage mass as determined by the Statistical Weighted Average mass determination method.
TP&E	---	Test Planning and Evaluation

TABLE AP 9-1 (Sheet 12 of 13)
GLOSSARY AND ABBREVIATIONS

Abbreviations	Terms	Definition
---	Unusable propellants	Those propellants remaining after a propellant depletion cutoff. This includes the propellant in the tank below the depletion sensor, propellant in the feed duct, and trapped propellants. It does not include sensor lag time or the propellant consumed during engine cutoff but does include sensor time delay
U/R	---	Ullage rocket
---	Usable residual	Propellants in excess of trapped propellants left onboard a stage after powered flight has been terminated by some specified cutoff criteria
v	---	Volt
V_E	---	Relative velocity
V_I	---	Inertial velocity
V_{RM}	---	Freestream velocity
V_W	---	Wind speed
VAB	---	Vehicle Assembly Building, KSC, Florida
vac	---	Voltage, alternating current
vdc	---	Voltage, direct current
VCO	---	Voltage controlled oscillator
VHF	---	Very high frequency
VSE	---	Vehicle support equipment
VSWR	---	Voltage standing wave ratio
W	---	Watt
WRO	---	DAC work release order
wt	---	Weight
$\dot{W}_T$	---	Time rate of change of total vehicle weight

TABLE AP 9-1 (Sheet 13 of 13)
GLOSSARY AND ABBREVIATIONS

Abbreviations	Terms	Definition
X_E	---	Downrange distance
$\dot{X}_E$	---	Downrange velocity
Y	---	Yaw
Y_E	---	Vertical distance
$\dot{Y}_E$	---	Vertical velocity
Z_E	---	Crossrange distance
$\dot{Z}_E$	---	Crossrange velocity
α_P	---	Pitch angle of attack
α_Y	---	Yaw angle of attack
γ_{1_I}'	---	Inertial flight path elevation angle
γ_{2_I}'	---	Inertial flight path azimuth angle
μ	---	Longitude
μv	---	Microvolt
αq	---	Product of angle of attack and dynamic pressure
γ_1	---	Earth fixed flight path elevation angle

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KABB Weight Control
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